AIRCRAFT & MISSILES

A Chilton Publication APPLIED ENGINEERING FOR THE AEROSPACE INDUSTRIES April, 1960

What's Behind the VTOL Design Dilemma?...P 17

THE GEM—A NEW BREED OF AIRCRAFT . . . P 31

Design of the Mercury Capsule and Systems . . . P 26

Failure of any part of a missile—be it the mighty Atlas, Jupiter or Thor—can mean failure of the mission. That's why the complex connections in the ducting systems of these and other missiles are silver brazed. These connections must stand up under 6,000 psi; they are tested to 12,000 psi.

In lines made to specifications by Flexonics Corporation, Maywood, Illinois, silver brazing joins a corrugated flexible pressure carrier, a braid sleeve and a coupling nipple—all of stainless steel; it permits joining all of these elements of the assembly without danger of annealing the pressure-carrying flex or the restraining braid as welding might do.

Assemblies designed for 6,000 psi operating pressure are required to withstand a 12,000 psi test and take four times their normal operating pressure before failure. They may also be required to pass a flame test in order to meet specifications.

The silver-brazed connections are used on hydraulic and pneumatic systems, fuel drain lines and vent tubes. Some of these applications involve rigorous service with extreme pressure shocks accompanied by sudden elevations of temperature, which may go from −60° to 400-600° F in a matter of seconds.

A more "high level" endorsement of Handy & Harman silver alloy brazing is not available. On the ground or in the air, the qualities of this remarkable metal joining method apply; strength, ease of production, cost, gas and liquid joint tightness to name a few. The entire brazing story is yours merely for the asking. Inquiries and metals-joining "problem exposure" may be addressed to Handy & Harman, 82 Fulton Street, New York 38, N. Y. We welcome the opportunity to work with you.

Your NO. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN

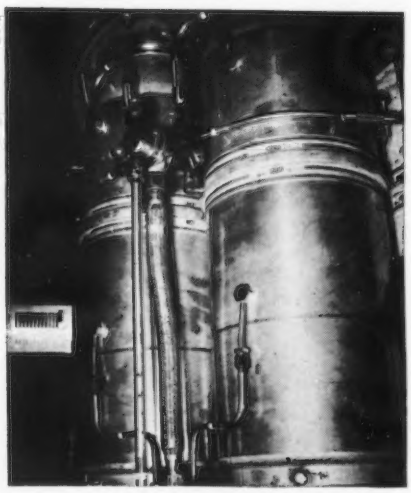
General Offices: 82 Fulton St., New York 38, N. Y.

DISTRIBUTORS IN PRINCIPAL CITIES

No Margin Here for joint failure!

Assemblies in ATLAS Missile **HANDY & HARMAN** Silver Brazed

Intercontinental Atlas missile being made ready for launching.



Close-ups of missile section, showing silver alloy brazed ducting assembly.

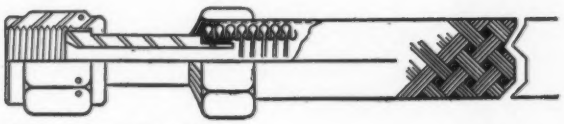
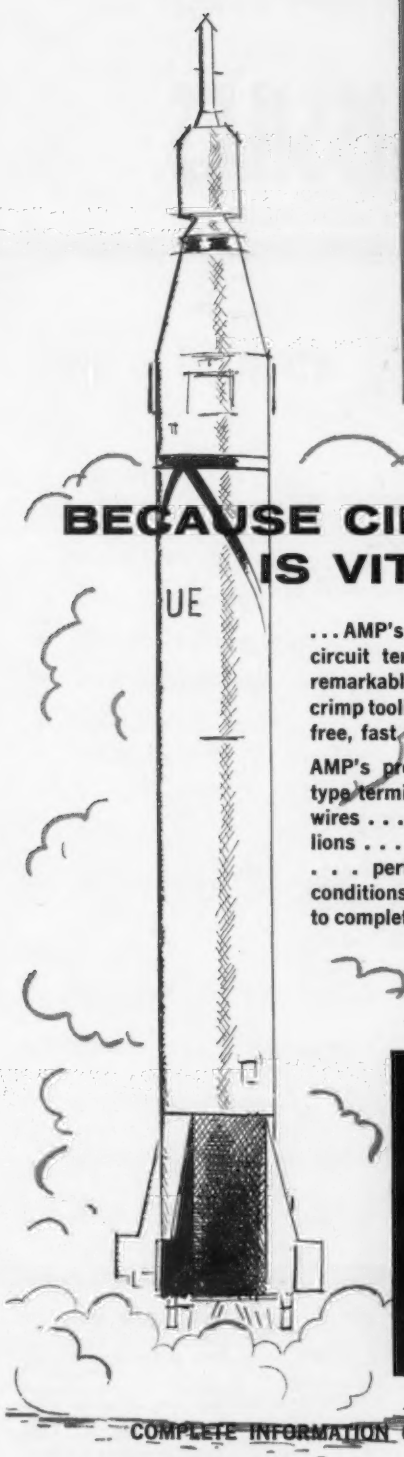


Diagram of pressure carrier.

FOR A GOOD START: BULLETIN 20.

This informative booklet gives a good picture of silver brazing and its benefits...includes details on alloys, heating methods, joint design and production techniques. Write for your copy.

Circle 1 on Inquiry Card



STRATO-THERM TERMINALS AND SPLICES

- up to 1200°F. operating temperature
- solid, stranded or combination conductors
- shock and corrosion resistant
- wire size range 22-10 AWG
- serrated inner barrel for maximum tensile strength

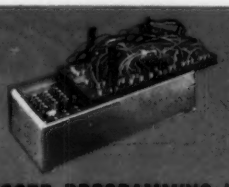
CERTI-SEAL SPLICES
AMPLI-NYL TERMINALS AND SPLICES

- combined wire size range 22-2/0 AWG
- exceed millivolt-drop specifications
- finest nylon pre-insulation
- shock and corrosion resistant
- color coded by wire size

BECAUSE CIRCUIT RELIABILITY IS VITAL . . .

. . . AMP's product is more than fine circuit terminals . . . more than remarkably precise compression-crimp tooling . . . more than an error free, fast method of attachment.

AMP's product is finished crimp-type terminations on your circuitry wires . . . by the hundreds or millions . . . of the highest reliability . . . performing under gruelling conditions . . . from basic terminals to complete patchcord systems.

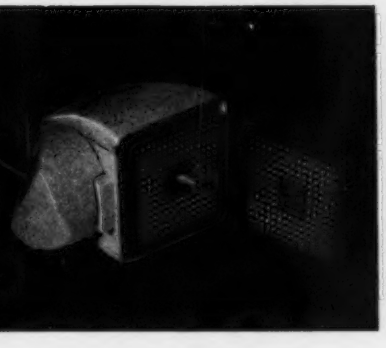


PATCHCORD PROGRAMMING UNITS
(Airborne "240" shown)

- universal or shielded systems
- patented wiping action pre-cleans pins and contact springs
- nylon sleeve insulates and firmly seats patchcord pin in board
- contacts have rear board accommodation for taper pins to provide reliable solderless lead terminations

200 CONTACT CABLE CONNECTORS

- extremely reliable disconnect for ground electronic and instrumentation application
- connector can be electrically disengaged without mechanical separation
- five indexed positions to permit strain-free cable exit
- identical inserts and contacts in both halves
- polarized to prevent improper coupling—has numbered cavities to assure proper circuit identification



COMPLETE INFORMATION ON THESE FOUR PRODUCT LINES IS AVAILABLE ON REQUEST.

AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

A-MP products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Japan

April, 1960 *Volume 3, Number 4*

AIRCRAFT & MISSILES

APPLIED ENGINEERING FOR THE AEROSPACE INDUSTRIES

Features

PAGE

17 **What's Behind The VTOL/STOL Dilemma?**
After six years of research and test-bed flight designers are in disagreement over best design concept.

22 **Helicopter vs. Tilt-Wing vs. Fixed-Wing VTOL**
Two prominent engineers "state the case" for their VTOL designs; AHS President warns they have lost basic advantage of classic VTOL.

26 **Design of Mercury Capsule and Systems**
Cobalt and titanium alloy make up shell; necessary complexity in systems caused by auto-manual capability.

32 **The GEM—A New Breed of Aircraft**
A report on state-of-the-art in ground effect machines reveals several approaches to riding on cushion of air.

38 **Can VTOL Rotor Concept Be Used for Re-entry?**
Bell Research Dept. examines possibilities; Approach likened to autorotating helicopter descent.

42 **A Plan to Increase Helicopter Range Sixfold**
World mobility could be provided by floating fuel-wing; Aerodynamic lift supports hinged-wing and fuel load.

45 **The VTOL Transport—Design Selection**
Hiller details reasons for choosing turboprop and tilt-wing combination for X-18.

49 **Coleopter—VTOL with Mach 3 Potential**
French plan to use circular wing as huge ramjet; Present turbojet will remain for takeoff and landing.

51 **Vibration Nomogram**
Handy tool for determining natural frequency of circular plates; Part I of III.

Staff

GEORGE T. HOOK, Publisher
W. THOMAS H. MacNEW, Editor

EDITORIAL

JOHN P. KUSHNERICK, Managing Editor
S. PETER KAPRIELYAN, Technical Editor
HARRY CASTERLIN, Art and Editorial Production Mgr.
PETER R. SIGMUND, News Editor
MARCUS AINSWORTH, Statistical Editor
HAROLD M. NELSON, Specifications Editor
HOWARD KOHLBRENNER, Art Director
ROBERT GUNNING, Readability Consultant
HARRY R. KAUCK, Technical Illustrator

REGIONAL and FOREIGN EDITORS

Los Angeles—J. PHILIP GEDDES, Technical Editor, West Coast
Detroit—JOSEPH GESCHELIN, Technical
HUGH C. QUINN, News
Washington—GEORGE H. BAKER, Chief
NEIL R. REGEIMBAL, News
RALPH W. CROSBY, News
Washington Member, Editorial Board—PAUL WOOTON
Europe—RONALD A. COLE

BUSINESS

BENNETT H. HORCHLER, Assistant Publisher
E. H. MILLER, Advertising Manager
JAMES CADAGAN, Circulation Manager
JOHN H. KOFRON, Director of Research
JOHN H. DAVIS, Marketing Research

REGIONAL SALES MANAGERS

Atlanta—JOHN W. SANGSTON
911 Wm. Oliver Bldg., 32 Peachtree St., N.E.
JAckson 3-6791
Chicago—RICHARD P. McCLANAHAN
360 N. Michigan Ave. RAndolph 6-2166
Cleveland—ROBERT COBURN
930 B. F. Keith Bldg. SUperior 1-2860
Dallas—WILLIAM J. SMYTH
Meadows Bldg. EMerson 8-4751
Los Angeles—JACK KAY
198 S. Alvarado St. DUnkirk 7-4337
New York—TED DRISCOLL
100 E. 42nd St. OXford 7-3400
Philadelphia—GEORGE ISHERWOOD
Chestnut & 56th Sts. SHerwood 8-2000
San Francisco—DON MAY
1355 Market St. UNderhill 1-9737

THE COVER STORY

Prime objective in the Mercury program is recovery of a manned capsule from space. It is NASA's highest priority project. Ground tests, like the wind-tunnel set up shown, and flight tests, will prove capsule and systems design before first manned shot in 1961. See page 26.

Departments

PAGE		PAGE	
4	Editorial	59	New Electronic Products
8	Reader's Orbit	61	New For Production
11	Data Capsule	63	New Books and Reports
15	Your Datebook	65	Men on the Move
53	Worth Asking For		
54	New Materials		
57	New Parts and Components		

Industry Notes

PAGE		PAGE	
66	British VTOL Fan Design	71	R & D Briefs
69	NASA VTOL Report	71	Production Techniques
69	Aerospace Log	72	Contracts
70	Mercury Path Indicator	74	New Facilities
70	Mercury Nerve Center	75	Business Moves

CHILTON COMPANY, OFFICERS AND DIRECTORS:
President. G. C. BUZBY
Vice Presidents
P. M. FAHRENDORF
LEONARD V. ROWLANDS
GEORGE T. HOOK
ROBERT E. McKENNA
Treasurer: WILLIAM H. VALLAR
MAURICE E. COX
EVERIT B. TERHUNE, JR.
FRANK P. TIGHE
RUSSELL W. CASE, JR.
CHARLES A. S. HEINLE
JOHN H. KOFRON
Comptroller: STANLEY APPLEBY

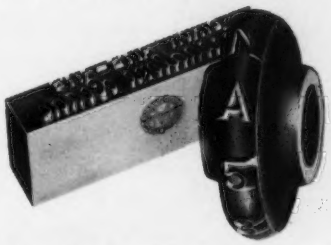
Editorial and Executive Offices: Chestnut and 56th Sts., Philadelphia 39, Pa. SHerwood 8-2000.

BPA NBP

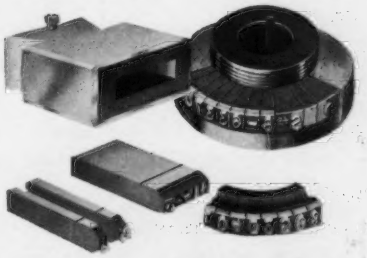
Accepted as controlled circulation publication at Philadelphia, Pa. Copyright 1960 by Chilton Company. Published monthly. Subscription rates: United States and Canada, $10.00 per year. Single copies $1.00, special issues $2.00. Foreign $20.00 per year—single copies $2.00, special issues $3.00 per copy.

MARKING DIES

Matthews Press Stamping Dies are machined, engraved, and heat treated from a choice of over 50 grades of tool steel to provide the most suitable marking for your application.



Roller dies and Flat Roll dies provide the finest marking with the least effort. Precision engraving of correct side bevels provides stress free marking and long die life.



Holders and type for flat and roll marking designed with the same exactness are ideal where frequent changeover is required.

For further information write

JAS. H. MATTHEWS & CO.
3962 FORBES AVENUE
PITTSBURGH 13, PA.

Circle 5 on Inquiry Card

The Next "Gap"— VTOL/STOL Airpower?

Off to another lag with a big rush. Not space this time, but VTOL/STOL airborne mobility. How much money is allotted to VTOL/STOL? Too little! So, along comes '65 and we won't have what it takes—again.

Concern over the missile race has caused sad neglect in other areas of our defense posture. Vertical and short take-off aircraft funding should go hand-in-hand with missile mobility for the defense mission that the military has outlined.

One of the biggest problems today is anti-submarine warfare (ASW). Here's one area where VTOL's can do an excellent job. Needed are increased range and payload. Electronic equipment must be modified to eliminate noise pickup from the aircraft, namely the power plant and rotor.

Still another mission for such a craft, supply Polaris missiles to the nuclear submarine fleet. VTOL's attached to surface ships would make for even less vulnerability of the subs, if the VTOL's had a range of 2000 to 3000 miles. Think of the mobility of such a striking force.

With a ban on nuclear warfare in the offing, we must also have craft for airborne assault to achieve vertical envelopment. Such aircraft must be able to operate with little or no airfield. To support ground troops the Mach 2 VTOL/STOL fighter-bomber is a must on the list, as well as rescue and logistics support aircraft.

Some monies have been coughed-up, but again on a hit and miss basis. There is no stated policy by the military. Is it possible after six years of varied research and spending that enough facts have not been assembled to make an intelligent evaluation of the problem?

Are we in for another hassle of investigations when we fall flat on our face in the VTOL/STOL area? We certainly don't want confused spending and a lot of hindsight by '65.

All of the VTOL/STOL makers certainly would like to know the direction the Armed Services want to take and then go all out to assist those Services. Intelligent planning could give us a terrific lead over all world competitors.

We're supposed to have a well-rounded defense arm—missiles can't do everything.

Tom MacNew

Editor

SOME PARTS OF THE FUTURE CAN BE SHAPED ONLY AT THE HUFFORD SPIN FORGE FACILITY

Your source for complex and/or massive surface-of-revolution components, until now "too difficult and expensive to attempt," is the Hufford Spin Forge Facility at El Segundo, California. Here, Hufford Engineering Services, working closely with Hufford customers, is advancing hour by hour the threshold of spin forge applicability. Giant, fully automated Spin Forges are capable of shear forming a part 10 feet in diameter, 30 feet long. They can produce one part or a multitude of identical parts from high strength metals (to 1¾" wall thickness) in minutes, whereas former methods would take days. For assistance in handling your surface-of-revolution parts production problems, contact The Hufford Corporation, 1700 E. Grand Ave., El Segundo, Calif.

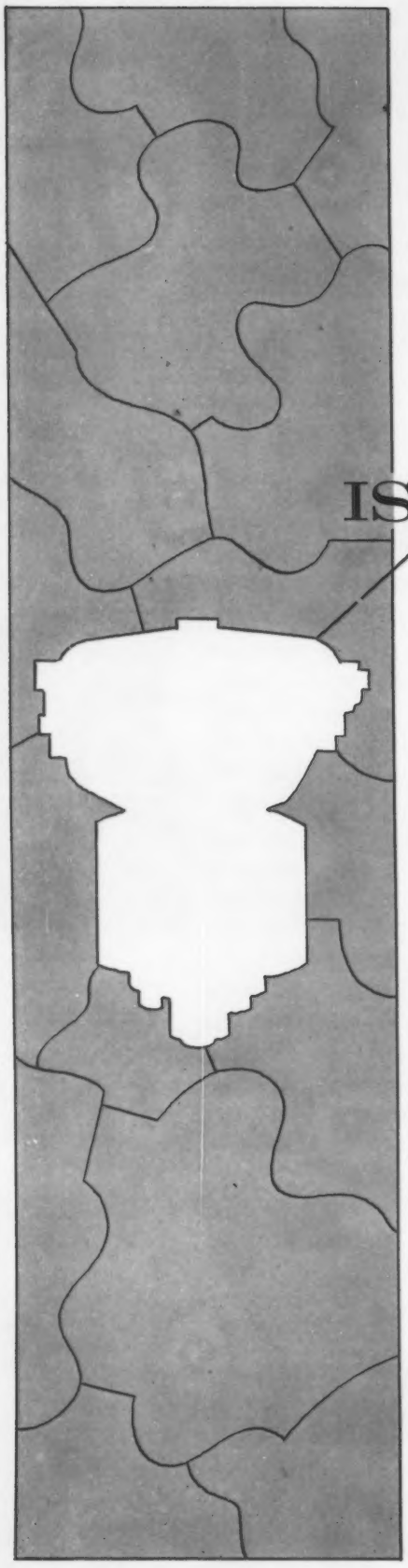
HUFFORD

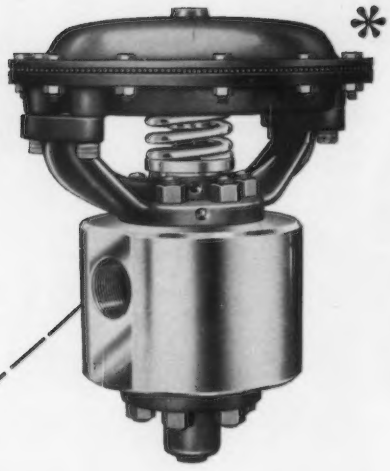
a division of The **SIEGLER** Corporation

SIEGLER

Ad No. 105

Circle 6 on Inquiry Card





IS THIS* THE MISSING PIECE?

Does control of high pressure water or hydraulic fluid in launching, test or ground support equipment circuits have you puzzled?

Here's the solution. The Sinclair-Collins diaphragm operated valve illustrated controls 6000 psi pressure at high flow rates. S-C valves offer positive, fast control, bubble-tight sealing, compact size and ample safety factors. Bodies are machined from aluminum bronze billets for strength plus resistance to cavitation and corrosion . . . stems are stainless steel with Stellited seating surfaces for long life and resistance to cutting or wire drawing.

Sizes range from 1/2 to 2 in. NPT; screw mounted; 2 and 3-way types; remote or direct electro-pneumatic control. For special applications, valves may be furnished with stainless or molybdenum steel billet bodies, for screw, screw-in flange or butt welding end mounting. Your Sinclair-Collins Field Engineer can provide application engineering recommendations.

For more information, write for free Bulletin S-C 59. Address: Sinclair-Collins Valve Company, Akron 9, Ohio, Dept. AMM-460.

The SINCLAIR-COLLINS VALVE Co.

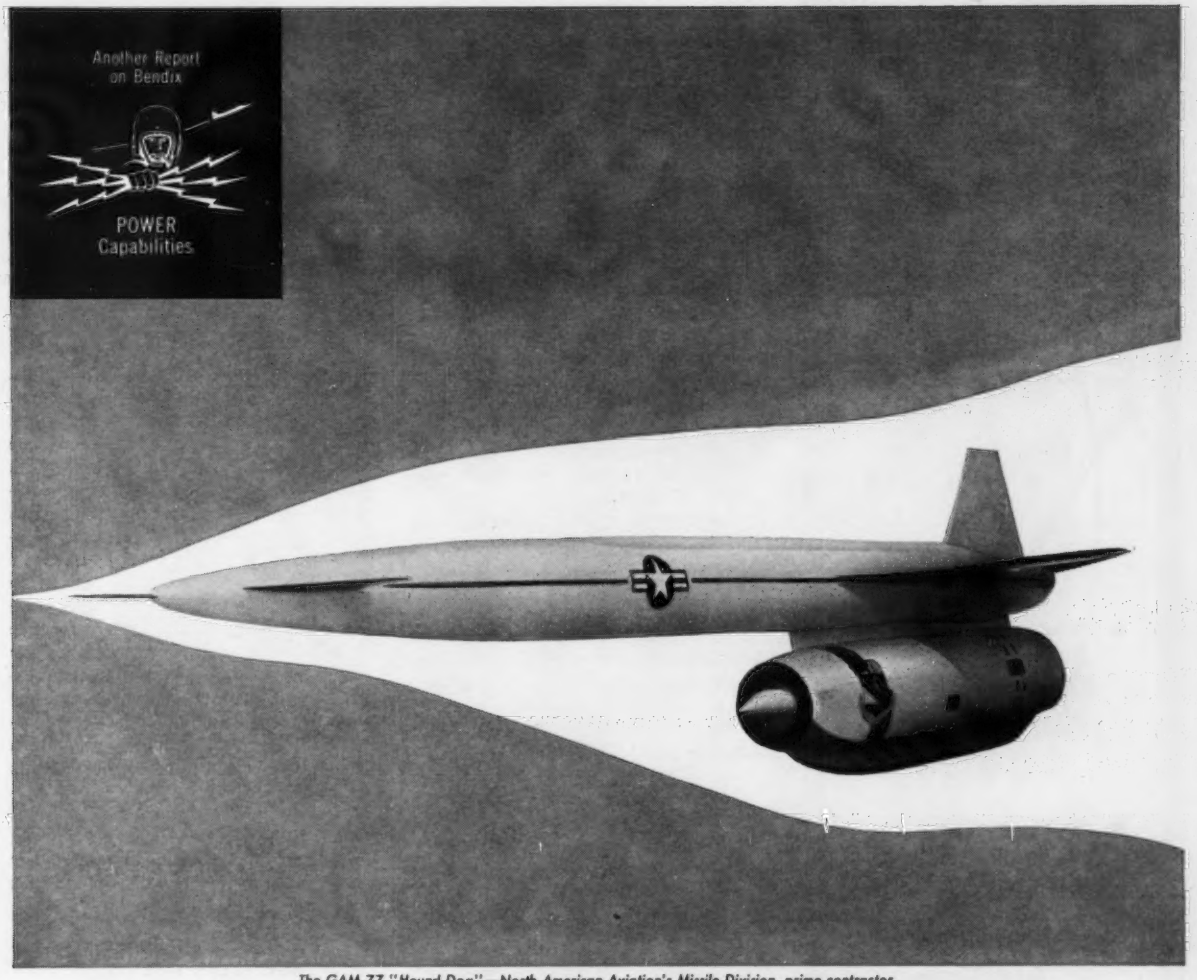
AKRON, OHIO

DIVISION OF INTERNATIONAL BASIC ECONOMY CORPORATION (IBEC)

Other INDUSTRIAL DIVISIONS of IBEC: The Bellows Co., Akron, Ohio · Volvair, Akron, Ohio · V. D. Anderson Co., Cleveland, Ohio

* Sinclair-Collins 6000 psi control valves

8121



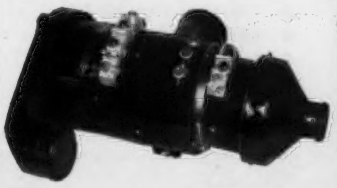
The GAM-77 "Hound Dog"—North American Aviation's Missile Division, prime contractor. This air-to-surface missile is carried by heavy bombers of USAF's Strategic Air Command.

BENDIX AC/DC PACKAGE GENERATES DEPENDABLE IN-FLIGHT ELECTRICAL POWER FOR "HOUND DOG"

The "Hound Dog" missile adds still more reach and punch to SAC's long arm. Carried by a B-52 bomber, the missile can be launched several hundred miles away from the target, and is capable of delivering a nuclear payload.

Before launching, the missile's electrical needs are supplied by the mother ship. Once "Hound Dog" is on its own, a Bendix® AC/DC generator fully meets electrical power demands. In a great new breakthrough in voltage control, the unit is equipped with a Bendix transistorized static AC/DC voltage regulator. The DC capacity of this Bendix AC/DC generator is provided with an addition of only five pounds in generator weight. Here is another example of the Bendix Red Bank concept of lightweight, reliable AC/DC power packages.

Get further details from RED BANK GENERAL PRODUCTS DEPARTMENT.



"Hound Dogs' " Bendix AC/DC Generator, a brush-type unit rated at 9 KVA, 3 phase, 400 cycle, 120/208 volts AC; 60 amps, 28 volts DC.

GENERAL PRODUCTS DEPARTMENT

Red Bank Division

EATONTOWN, NEW JERSEY

Bendix AVIATION CORPORATION

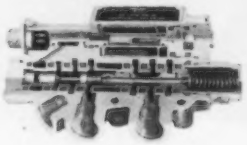
West Coast Office: 117 E. Providencia, Burbank, Calif.
Export Sales & Service: Bendix International, 205 E. 42nd St., New York 17, N. Y.
Canadian Affiliate: Aviation Electric, Ltd., P.O. Box 6102, Montreal, Quebec

RELIABILITY
AND
PERFORMANCE
are our main products

First, imaginative design; then experienced thoroughness through development, tooling, production, assembly and tests, all under strict quality control in an unusually well equipped plant . . . we can help you solve your special problems . . .

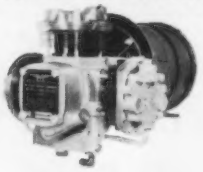
- BRAKE VALVES

- TRANSFER VALVES



- RELIEF VALVES

- COMPACT COMPRESSORS



also

- SOLENOID VALVES
- SELECTOR VALVES
- SHUTTLE VALVES
- PRESSURE REDUCERS
- FUEL PUMPS
- DEHYDRATORS
- COMPLEX PACKAGES

WRITE, wire, or phone for data, quotations and service.

M. C. MANUFACTURING CO.
LAKE ORION, MICHIGAN
PHONE: MYRTLE 2-2711

Circle 44 on Inquiry Card

Reader's Orbit

Reading Between The Lines

. . . As lubrication engineer on the B-58 Hustler . . . was very interested in "Lubricating X-15's Hot Bearings" (A&M Feb. '59). Our control-surface hinge-pin problem closely resembles that of the X-15, except that our loads are higher . . . and, our lubrication interval is "on assembly"—for the life of the airplane, 2000 hr. Temperature requirements are from —65 to 550° F, in some areas.

We are at a loss to understand how AeroShell 5A meets Air Force requirement of —65° F on military aircraft.

. . . would also appreciate knowing how maintenance personnel can keep a grease gun with 60 psi at the nozzle on a Zerk fitting . . . Convair, as well as other companies, use MS 15000 series fittings. Where design demands it, NAS 516 type are used.

. . . appreciate your fine articles . . . more on lubrication.

E. B. Palmer
Senior Design Engineer
Convair-Fort Worth

A slight amount of confusion has resulted from reader Palmer's excellent knowledge of lubricant specs and his reading between the lines of the published article. Article does not state that Aeroshell 5A meets —65°F requirements . . . it doesn't . . . only high temperature requirements are discussed in the article. At time of selection of X-15 lubricant MIL-G-3545 was used . . . this requires 0° F operation which Aeroshell met (has since been improved). High temp requirement seemed more important than low, and the usual —65° F requirement was compromised to get a commercially available grease. Second item to get confused was fittings and pressures. Article states clearly that Zerk fittings were used in tests . . . aircraft fittings are hydraulic type as Mr. Palmer suspects. Finally, grease pressure at fitting is actually over 2000 psi . . . the 60 psi air pressure supplied by the air-driven pump is stepped up about 36 times.

Tall Order . . . In Any Time

. . . most anxious to receive information . . . concerning typical selling expenses experienced in a specialized manufacturing field; namely custom designed and developed defense products such as SIC#1999 — Ordnance Accessories (N.E.C.) . . . #3729 — Aircraft Parts, and Auxiliary Equipment (N.E.C.) including related products manufactured to detail drawings.

Of particular interest . . . data establishing a range of selling expense in relation to sales volume with particular reference to such expense elements as home office, field office and advertising. Categorizing the expense information by convenient sales volume groupings would be most helpful.

Also, any information available concerning dollar cost per field man would be helpful . . . have reference to field office expense, communication costs, travel, etc. as would be generated by a graduate engineer averaging weekly to monthly coverage of approximately twenty customers within three to four hundred miles of his field office.

Kindly advise at your earliest convenience as to whether or not you have such information available or can recommend where it might promptly be obtained.

E. F. Pain
V.P.-Sales & Engineering
Aero Supply Mfg. Co.

Readers who feel they can part with such information should write directly to Mr. Pain.

Informed Stockholders

. . . We believe the article ("How Navy Will Monitor Polaris Firings," A&M Feb. '59) would be of interest to our stockholders, and we ask permission to reprint . . . giving proper credit.

George Ewing
Interstate Electronics Corp.

You may reprint. Happy you have selected our West Coast Editor's article as a means of keeping your stockholders informed.

Missile Directory

. . . We recently published our Missile Directory and want to thank you for your cooperation in allowing us to reproduce the pages from your Aircraft & Missiles Handbook (1959) . . . looking forward to the 1960 edition.

E. W. Edmonds, Jr., Lt. Col.
Headquarters Eighth Air Force

✦

Over 15,000,000 ft. of Superior stainless hydraulic tubing helps today's aircraft and missiles to operate efficiently

In the past 5 years more than 15,000,000 ft. of Superior stainless steel aircraft hydraulic tubing has been produced for use in military, commercial and private aircraft.

Here are some of the steps taken by Superior to make certain its aircraft quality hydraulic tubing not only meets specifications, but saves time and money by eliminating rejects and provides long, trouble-free service life.

Before material is released for production, it is metallographically checked for grain size and characteristics. A chemical analysis is made, and wall runout is checked. Samples are pickled and checked for carburization. In production, intermediate annealing operations are 100% automatically controlled. Checks are made for metallic chips and other foreign matter. Then, as a final inspection, all tubing is 100% hydrostatically and flare tested. We now produce to 18 current MIL, AMS and AN Specifications—and can supply many *extras* far above normal specifications.

If you have a problem involving aircraft quality tubing and want the best combination of physical and mechanical properties, including high strength, ductility, fatigue and corrosion resistance, and good working qualities, consult us. We specialize in Seamless and WELDRAWN® stainless steel hydraulic tubing in AISI Types 304, 321 and 347 and in sizes from .012 through 1.125 in. OD. Send for Catalog 21 on stainless steel tubing. Superior Tube Company, 2053 Germantown Ave., Norristown, Pa.

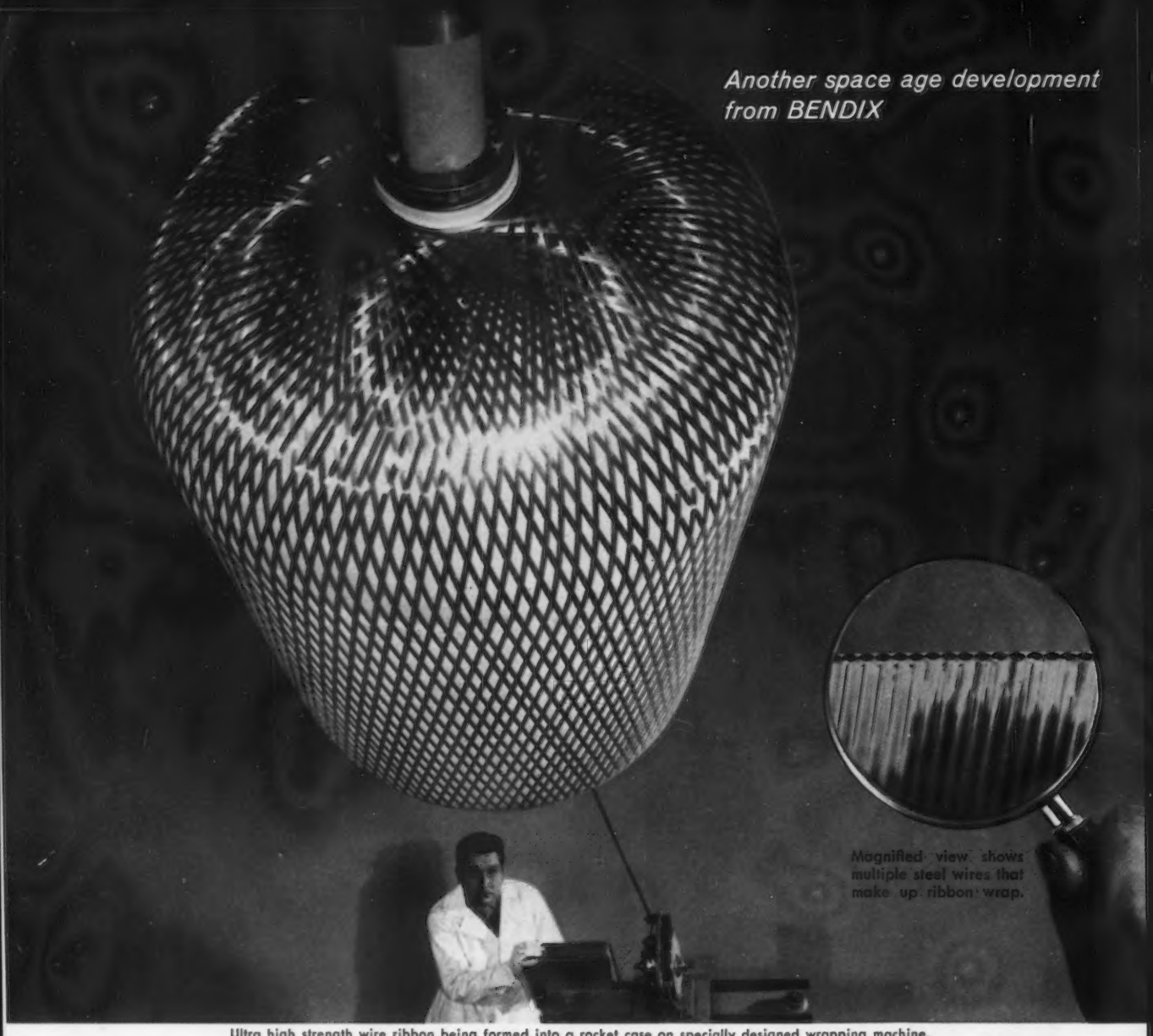
Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST



Ultra high strength wire ribbon being formed into a rocket case on specially designed wrapping machine.

UNIQUE BENDIX WIRE *RibbonWrap* REDUCES WEIGHT, INCREASES RELIABILITY OF ROCKET CASES

Bendix has licked the problems of weight and reliability in flight weight pressure vessels. Secret of the Bendix-developed rocket cases: many tiny ultra high strength steel wires formed by adhesive bonding into a highly efficient ribbon. Weight and distribution of the binding adhesive is precisely controlled. Result—rocket cases with test strength as high as 531,000 psi, *equivalent to a hoop stress of 350,000 psi UTS in a homogenous case.* A specially designed Bendix machine generates the rocket case. The best wrap pattern for each case is mathematically determined and precisely controlled. Finished product is a rocket case tailor-made for configuration, strength and reliability.

For more complete information, write Rocket Equipment, Bendix Products Division, South Bend, Indiana.

The Bendix wire RibbonWrap gives you these important advantages:

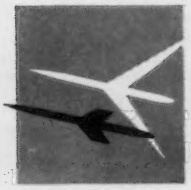
Design Flexibility
Controlled Minimum Weight
Close Tolerances
High Temperature Strength
Shortest Prototype or Production Lead Time
Automated for Low Cost
Inherent Reliability

Bendix PRODUCTS DIVISION South Bend, IND.

Bendix AVIATION CORPORATION

Circle 11 on Inquiry Card

Data Capsule



SUMMARY OF MANAGEMENT TRENDS AND TECHNICAL DEVELOPMENTS IN THE AEROSPACE INDUSTRIES

MISSILES AND SPACE VEHICLES

Design

NUCLEAR RAMJET plan applying air-propulsion principles to submarine-propulsion has been filed with the Patent Office by Boeing Aircraft.

FLYABLE PLASMA ENGINES are now being designed at Republic Aviation. Firm has completed a second experimental model of magnetic pinch plasma engine. It is considerably larger than the first, which ran continuously for 118 hr. Satellite and spaceship applications are planned.

PIONEER V contains the most powerful radio transmitter ever sent into space, a 150-watt UHF set. It sends data stored by "telebit" digital electronic unit. Paint pattern insures proper payload temperature. Lithium heat sinks prevent transmitter overheating.

Development

NUCLEAR ROCKET got a shot in the arm from AEC, which diverted $11,000,000 into Project Rover development. Nuclear propulsion may be ready for space vehicles within five years.

TEST STAND for single-chamber 1.5-million-lb-thrust engine is being built at Edwards AFB.

PROJECT TRANSIT navigation satellite is slated for launch this month.

PERSHING DEVELOPMENT is being kept as "tactical" as possible during Army R & D flight tests. Tactical ground support equipment, such as the XM-474 track-laying Pershing-transporter, is scheduled for early use.

JETEVATORS ON POLARIS remain out of exhaust stream until commanded by guidance to change thrust-vector. Navy calls this system, and Polaris thrust termination control, major breakthroughs in missilry.

BUILDING BLOCK ROCKET has been fired successfully at Aerojet-General's Sacramento plant. A solid-fuel type, it can be assembled according to varying mission demands.

Production

PULSE CODE MODULATION (PCM) telemetry system is being produced for Titan.

ABLE STAR is in production at Aerojet-General. Slated for use with Thor for launching Transit satellite, it has stop-restart ability.

DIRECTORY OF METALWORKING MACHINERY is now at the Government Printing Office. It is expected to be out by June. Defense Department also has Directory of Welding, Heat-Cutting and Metallizing Equipment near completion.

ATLAS HARD SITE PROTOTYPE is being built at Vandenberg AFB.

Procurement

TWO SATURN CONTRACTS are expected to be announced by about the middle of May. One is for the S-1V second stage of the early C-1 model. Other will be for one of the stages on later C-2 model. Eleven firms bid on the C-1 and about seven on the C-2.

AIRCRAFT

Design

BRITISH VTO fighter and close

support aircraft is expected to fly this Autumn. It is believed to be either the deflected jet or ducted fan variety . . . perhaps a combination of both. Called the P.1127, plane was designed by Hawker Aircraft.

GERMAN VTO design project is reportedly centered in Munich. Messerschmitt and Heinkle are said to be the chief airframe manufacturers in the work. The Bolkow organization will reportedly be responsible for the armament.

DORSAL-MOUNTED TEST WING is being fitted on an obsolete bomber at the College of Aeronautics, Cranfield. This "shark's fin" wing will be equipped for tests of theories developed by Dr. Lachman of Handley Page over the past ten years.

VERTOL 76 control system may be improved by elimination of directional fan on its tail. NASA's evaluation of the 76 at Langley Field winds up this Spring.

LOCKHEED ELECTRAS now have fixed air exit louvers flush with fuselage.

GROUND-EFFECT/STOL aircraft has been designed and wind-tunnel-tested in model form. This Vertol model uses a ducted fan to lift the craft two or three fet above the ground. Plane then takes off in STOL fashion as air is ejected from wing trailing edge.

Development

AUTOMATIC LANDING SYSTEM which can land two airplanes a minute during bad weather is in development at Bell Aircraft.

AIR FORCE PLANS reportedly now favor development of an STOL (short takeoff and landing) fighter for the mid 1960's The Mach 1 STOL would get most of uncommitted Fiscal '60 Defense Department funds set aside for an operational VTOL. Rest of these funds would go towards R&D on a VTOL fighter for the 70's. Oral presentations by industry have been underway at Wright Air Development Division on a VTOL or STOL transport for the mid-sixties.

ARMY STOL/VTOL PLANS center around need for new light observation craft, and for a forward area transport. Helicopter appears to occupy a favored place for aerial reconnaissance. STOL seems to be favored for the transport.

AVROCAR is undergoing wind-tunnel tests at NASA's Ames Research Center.

GERMAN VTOL CRAFT will reportedly be developed with Rolls-Royce engine called the RB.153. This is believed a development of the RB.145 which was specially designed for vertical takeoff operations.

NEW FRENCH ENGINE for light aircraft is being flight-tested. This air-cooled unit developed by Potez is regarded as first real competitor of the U. S. Continental and Lycomings.

ICE DETECTION DEVICE developed by Armour Research Foundation uses two translucent plastic rods placed a fraction of an inch apart on the plane's wing. Ice causes light to refract from first rod into second rod, where it activates an electric eye.

BUG WIND TUNNEL is operating at Chance Vought's Aeronautics Div. Bees and flies are blasted against B-52 windshields from 7-inch diam. tube. Special chemical on windshield prevents insect smears and water collection.

Production

DOPPLER NAVIGATION UNITS for the Royal Navy are in production at Ryan Electronics. Called AN/APN-97A, units help anti-submarine helicopters maintain hovering.

X-15 POWERPLANTS, now being produced and tested at Thiokol's Reaction Motors Div., are actual flight-type engines. Previous model was developed for ground runup testing. First of the flight powerplants is slated for delivery to NASA and the Air Force in the near future. This "big engine" may power the X-15 by the middle of May, about six weeks after delivery.

Procurement

CONGRESSIONAL INVESTIGATORS are examining past procurement of F7U fighters, T2V trainers and APS-44A radar sets. Comptroller General Joseph Campbell charges the Navy spent $607,800,000 on them although it knew of serious deficiencies.

Falcon missiles travel "first class" in containers secured by LINK-LOCK

Fourteen No. 2 LINK-LOCK fasteners → maintain a pressure-tight seal around cover of Falcon cases.

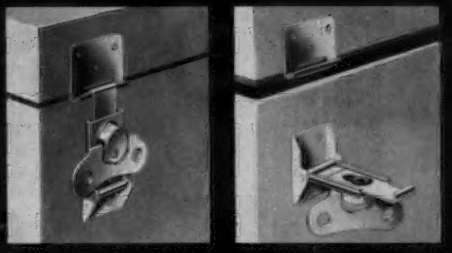
Before they take to the skies, Falcon air-to-air guided missiles are shipped or stored in containers sealed pressure-tight by Simmons LINK-LOCK fasteners.

These precisely engineered fabricated aluminum cases are produced to Hughes Aircraft Company specifications by the following companies: Vendorlator Manufacturing Co., Fresno, California; Allison Steel Manufacturing Co., Phoenix, Arizona; Avco Corporation, Crosley Division, Richmond, Indiana.

Features like these make the LINK-LOCK ideal for use on military cases made to rigid specifications as well as on inexpensive commercial containers:

- Impact and drop resistant.
- Positive-locking without springs.
- High preloading and high load carrying capacity.
- Compact design—lies flat open or secured.
- 3 sizes, for heavy, medium, light duty.
- Flexible engagement latch design... can be varied to suit different applications.

Write for Catalog #1762. Contains complete details of LINK-LOCK and other Simmons Fasteners with unlimited money-saving applications. Samples and engineering service available on request.



Half-turn applies high closing pressure, counter-turn disengages for opening. LINK-LOCK lies flat open or closed.

SIMMONS
FASTENER CORPORATION
North Broadway, Albany 1, New York
QUICK-LOCK • SPRING-LOCK • ROTO-LOCK • LINK-LOCK
DUAL-LOCK • HINGE-LOCK
See our 8-page catalog in Sweet's Product Design File

Circle 12 on Inquiry Card

FORMULA FOR TOMORROW

Modern Machine Tools = Production Efficiency

THE MACHINE TOOL EXPOSITION - 1960

INTERNATIONAL AMPHITHEATRE
CHICAGO, ILLINOIS
SEPTEMBER 6-16

NATIONAL MACHINE TOOL BUILDERS' ASSOCIATION

MODERN MACHINE TOOLS
MMT=PE
PRODUCTION EFFICIENCY

Your Date Book

April 5-8
National Aeronautic Meeting
Society of Automotive Engineers
Commodore Hotel, N. Y.

April 6-8
National Meeting
Institute of Environmental Sciences
Biltmore, Hotel, Los Angeles

April 6-8
Conference on Structural Design of Space Vehicles
American Rocket Society
Biltmore Hotel, Santa Barbara, Calif.

April 11-13
Electrical Engineering in Space Technology
American Institute of Electrical Engineers
Hotel Baker, Dallas, Texas

April 12-13
Spring Technical Conference
Institute of Radio Engineers,
American Rocket Society
Hotel Alms, Cincinnati, O.

April 18-20
Symposium on Chemical Reactions in the Lower and Upper Atmosphere
Stanford Research Institute
Mark Hopkins Hotel, San Francisco

April 20-22
Meeting on Manned Space Stations
Institute of the Aeronautical Sciences
NASA, The Rand Corp.
Los Angeles, Calif.

April 25-29
41st Convention and Welding Exposition
American Welding Society
Biltmore Hotel, Los Angeles

April 27-28
Symposium on "Materials-Key to Space Flight"
American Society for Metals
Sheraton Gibson Hotel, Cincinnati

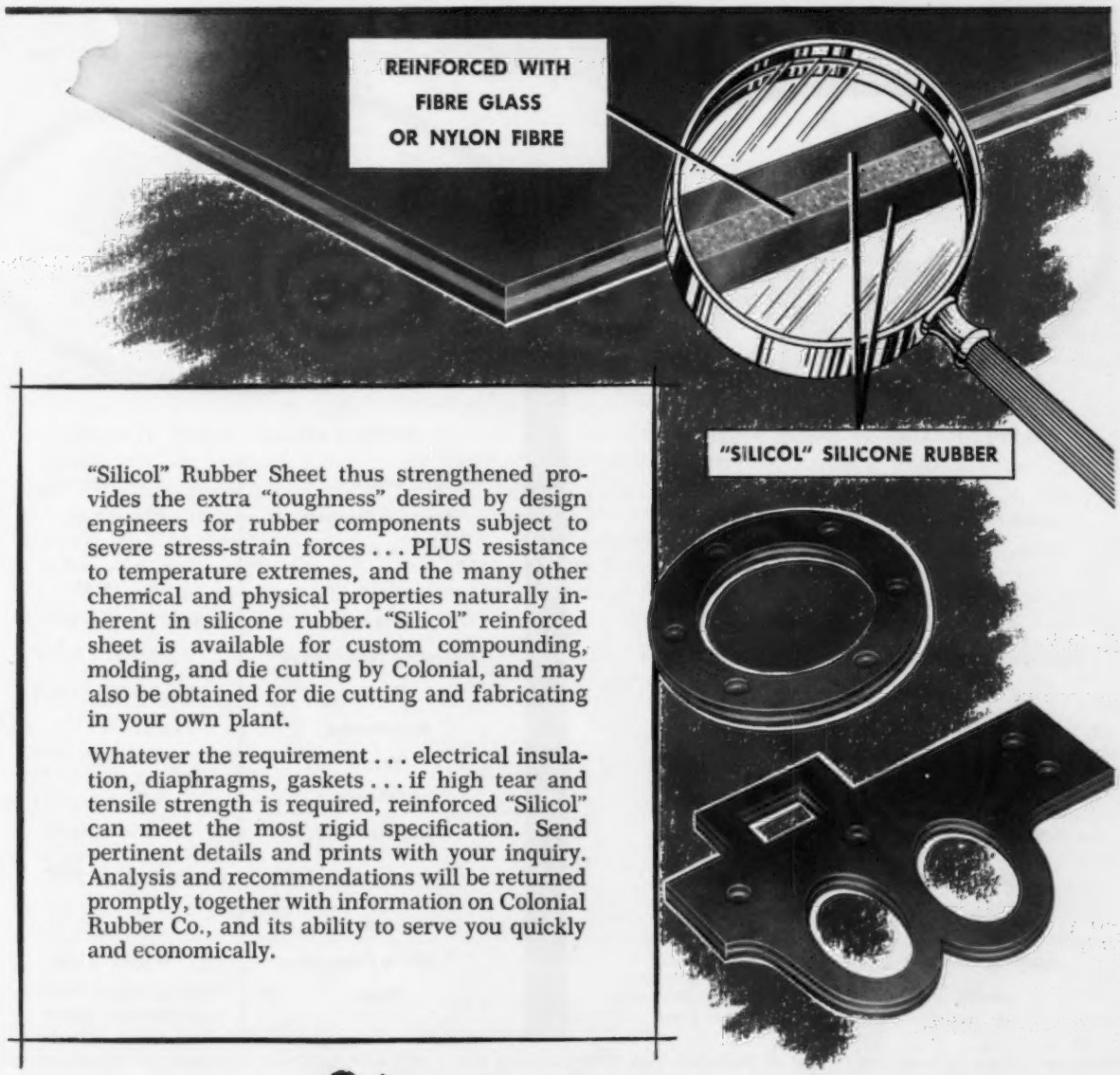
April 28-29
Symposium on "closed circuit respiratory systems"
Wright Air Development Div.
Wright Patterson AFB, O.

Circle 13 on Inquiry Card

• Design your seals and gaskets for

100% GREATER TENSILE and TEAR STRENGTH

with "SILICOL"* SILICONE RUBBER SHEET



"Silicol" Rubber Sheet thus strengthened provides the extra "toughness" desired by design engineers for rubber components subject to severe stress-strain forces . . . PLUS resistance to temperature extremes, and the many other chemical and physical properties naturally inherent in silicone rubber. "Silicol" reinforced sheet is available for custom compounding, molding, and die cutting by Colonial, and may also be obtained for die cutting and fabricating in your own plant.

Whatever the requirement . . . electrical insulation, diaphragms, gaskets . . . if high tear and tensile strength is required, reinforced "Silicol" can meet the most rigid specification. Send pertinent details and prints with your inquiry. Analysis and recommendations will be returned promptly, together with information on Colonial Rubber Co., and its ability to serve you quickly and economically.

VISIT COLONIAL AT
THE DESIGN
ENGINEERING SHOW
IN NEW YORK, MAY 23-26
BOOTH 934

*Reg. T.M. Colonial Rubber Co.

Colonial RUBBER COMPANY

706 Oakwood Street
RAVENNA, OHIO

AXminster 6-9611

1743-A

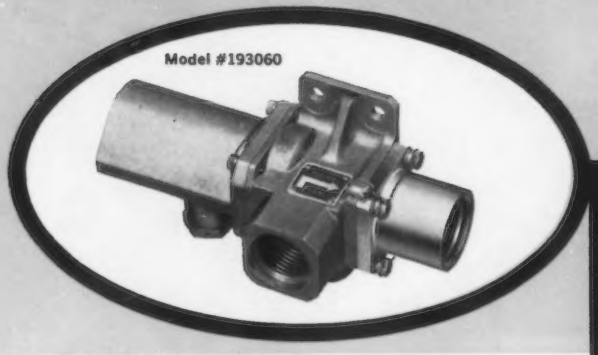
Now on Atlas, Titan & Centaur Missiles

LEONARD PILOT OPERATED RELIEF VALVES

with operating temperature range of −320°F to +200°F

These two Pilot Operated Relief Valves, currently in production at Leonard, have zero leakage over a temperature range of −320°F to +200°F, and withstand the extremes of shock and vibration. Featuring a unique pilot operated circuit, the units are small in size, and but 14 ounces in weight. Their reliability and accuracy has gained for them wide recognition as ideal missile components, as well as for many ground and static applications. The two valves shown are typical of the many relief valves that have been produced by Leonard which cover wide ranges of pressures, medias and flow conditions. Note the detailed specifications.

Please visit our Hospitality Suite at the ISA FLIGHT TEST SYMPOSIUM—May 2-5 • Hotel Del Coronado, San Diego, Calif.



SPECIFICATIONS • MODEL #193060	
Media	Helium
Cracking Pressure	385 psig max.
Reseat Pressure	370 min.
Flow	.15 lbs/sec.
Leakage	55 cc/min @−320°F
Operating Temperature	−320°F to +200°F
Vibration	30 G 10 to 2000 cps
Acceleration	20 G's
Weight	14 oz.
Overall Length	5.40 in.
Response Time	5 ms. to full open

DESIGN PARAMETERS • MODEL #193060	
Maximum Flow	.36 lbs/sec.
Cracking Pressure	250 to 1000 psig.
Media	GOX, Hydrogen, Nitrogen, and other gases

SPECIFICATIONS • MODEL #193200	
Media	Helium
Cracking Pressure	32 psig max.
Reseat Pressure	29 min.
Flow	.032 lbs/sec.
Leakage	5 cc/min @−320°F
Operating Temperature	−320°F to +200°F
Vibration	MIL-E-5272, Proc. 1
Acceleration	20 G's
Weight	14 oz.
Overall Length	6.00 in.
Response Time	5 ms. to full open

DESIGN PARAMETERS • MODEL #193200	
Maximum Flow	.2 lbs/sec.
Cracking Pressure	30 to 250 psig.
Media	GOX, Hydrogen, Nitrogen, and other gases

The relief valves featured are typical of the more than 200 precision pneumatic and hydraulic pressure control devices which have been developed during the past 10 years at Wallace O. Leonard, Inc., and are now standard equipment on all ICBM's. Leonard product classifications cover: **Regulators • Valves • Switches • Flow Restrictors • Primary Pressure Source • Servo Transducers—Flight Test Systems, Pressure Ratio Computers, Lox and Fuel Tank Level Computers • Systems—Tanking Computers, Primary Pressure Standards.**

Leonard craftsmen and advanced technical personnel have built an enviable reputation for superior products for missile guidance, control and ground support applications. May we have the pleasure of reviewing **your** specific requirements in these areas? For consultation and information please write to:

Eastern Sales Representatives: **BRIERLEY, DAVIS COMPANY**
332 Springfield Ave., Summit, N.J. • Telephone CRestview 3-7300 • TWX—SUMMIT NJ 355

LEONARD PASADENA

Wallace O. Leonard, Inc.
373 South Fair Oaks Avenue • Pasadena, California
Telephone SYcamore 2-7131 • TWX—PASA CAL 7321

AN **AIRCRAFT & MISSILES** SPECIAL STAFF REPORT

What's Behind the VTOL/STOL Dilemma?

Six years of research leaves experts in doubt on best overall configuration for winged VTOL craft; "Fan-in-wing" powerplant scheme could force course

After six years of research, experts still disagree on the optimum VTOL/STOL configuration.

No single design concept has yet been adaptable to both attack-aircraft and to transports, the difficulty being in making high-lift devices compatible with high speeds.

Indications are, however, that attractive VTOL power-plants will soon cause design efforts to funnel into more specific directions.

Influential Newcomer—A relative newcomer in the propulsion field is one of the forces that will cause a congealing of design trends. It is known as the ducted-fan concept, also fan-in-wing, or submerged fan. Engine thrust is diverted to the lifting fan for vertical and transition flight only. In forward flight, the fan is "out of the way" both aerodynamically and propulsion-wise.

It provides a versatility of design which allows application in the full aircraft spectrum, from heavy transport-to-light fighter. Propulsive efficiency lies between the turboprop and the turbojet.

Basic Approach — There are three basic methods of converting propulsive power to lift power in the fan-in-wing concept. They are:

- Shaft turbine
- Turbodrive
- Turbofan

In the shaft turbine, the lifting fan is driven directly from the shaft which drives the compressor in the main gas turbine. It provides an efficient system, for speed ranges typical of propeller driven aircraft.

The turbodrive is suited to transonic flight. The ducted fan is driven by a shaft connected to a secondary turbine in the main propulsion unit. It is closest to ducted fan state-of-the-art for high performance flight.

The turbofan eliminates shafting and gears. It is inherently the most reliable because it is the most simple. But, it suffers from the standpoint of immediate response and efficiency. There is some heat loss in the ducts which transport thermal energy from the main powerplant to the fan in the wing. This arrangement has great potential despite its current short comings. It is just slightly beyond the state-of-the-art for immediate use.

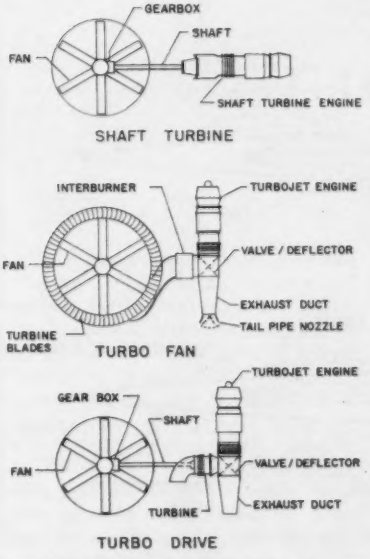


FIG. 1. BASIC DESIGN schemes for three ducted fan concepts are shown. Turbofan has great potential.

Ryan's Vertifan—One of the leaders in developing the turbofan approach is Ryan Aeronautical Co. Ducted, fan-in-wing jet power was first studied at Ryan in 1955. The concept presently known as "Vertifan" sprang from this research. In July, 1959 ARDC awarded Ryan a contract to study an entire "submerged-fan VTOL aircraft." General Electric's Aircraft Gas Turbine Div. has assisted in the study.

In Vertifan, jet engine thrust is the sole source of power for VTOL, and for transition from low forward speed to high speed. The power plant installation is basically conventional. Vertical takeoff is accomplished by diverting jet thrust to the free-turning fans buried in the wings (See fig. 1.) In the process, the high-energy, small mass-flow of the jet is converted to a low-energy high mass-flow with a decreased exit velocity. The result is an increase in vertical thrust.

The layout consists of an inlet, the jet engine itself, a diverter valve, a tailpipe and a tailpipe nozzle. The diverter valve is situated in the tailpipe and diverts jet engine exhaust

← Circle 17 on Inquiry Card

Ryan Vertifan concept shows potential for attack-aircraft and transports

into a scroll. This scroll surrounds a fan located in the chord plane of the wing. Around the periphery of the fan is a turbine ring with turbine blades attached. Above and below the fan on the wing upper and lower surfaces are wing vanes, or louvers. These vanes are perpendicular to the chord line during hovering allowing fan-moved air to go straight through.

During transition, the upper vanes slant forward, directing air into the fan. The lower vanes slant rearward, directing slipstream from the fan aft for forward acceleration.

Once stall speed is exceeded, the upper and lower vanes on the wings close, leaving a clean airfoil. Coincidentally, the diverter valve closes and allows the jet exhaust to go straight through the tailpipe. The airplane cruises as a conventional jet aircraft.

Control Stability — Hovering stability is essential. In a jet VTOL the obvious way to obtain reaction control for hovering or transition, is to duct the gas to the tail or nose of the aircraft. In Vertifan, rather than direct this air flow overboard through a nozzle, it will be used to power a tail fan, or a nose fan. A very large amount of thrust is obtainable compared to the amount of thrust obtained from a pure reaction nozzle. Further, if only a portion of this thrust is required for control, a certain amount is available to compensate for center of gravity shift.

Yaw control will also come from the forward and aft auxiliary control fans. Louvers, in this case, would be positioned to the left or right.

Roll control will be obtained from differential lift of the main fans in the wings.

Thrust-to-Lift — Fig. 3 shows the combinations of lift and thrust available in the Vertifan. The ordinate shows fan lift and the abscissa jet engine thrust. As an example, if 4000 lb of jet thrust is available, a 60-ft diam fan operating at 300 psf disk-loading will provide about 9000 lb of lift. In another case, if the same 4000 lb of jet thrust is available, a 10-ft diam fan operating at 110 psf disk-loading would provide about 12,000 lb lift.

Interburning — The actual size of the fan in the wing is important. In some cases it may turn out to be larger than the allowable wing-area. It is possible to reduce the design size of the fan with interburning. Interburning is a technique of introducing heat energy between the turbojet and the turbine fan. The energy increase is directly pro-

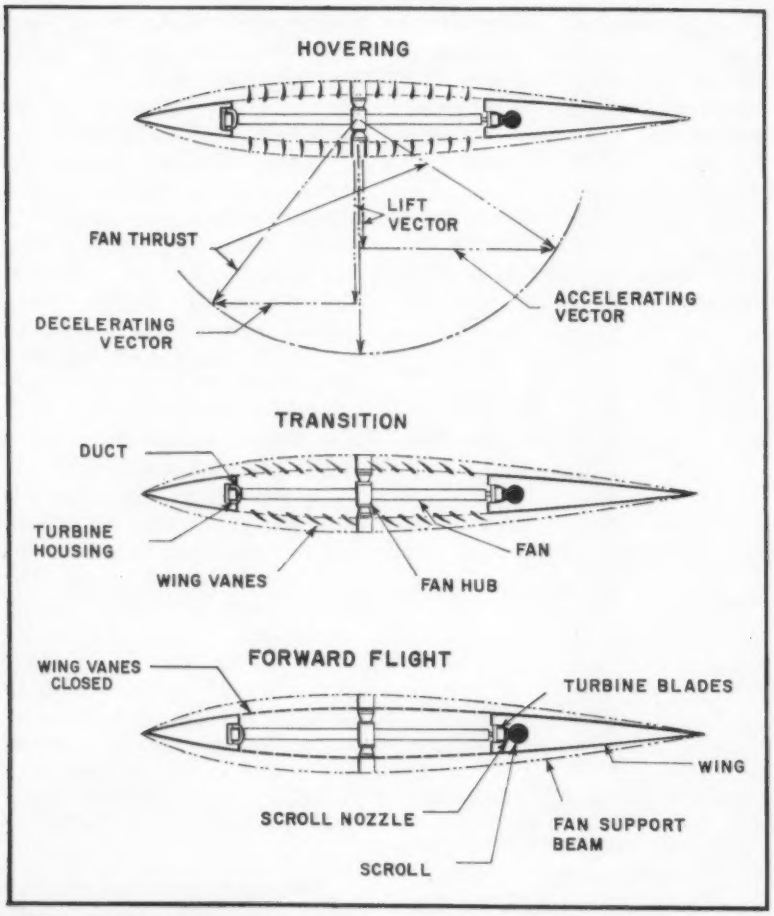


FIG. 2. RYAN'S VERTIFAN uses vanes on upper and lower surfaces of the wing to help guide air through fan-in-wing. Vanes are perpendicular to chord line in hover, closed to form a smooth airfoil in forward flight.

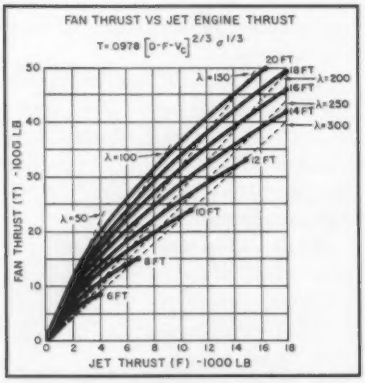


FIG. 3. THRUST-TO-LIFT ratios can be figured using ordinate as lift and abscissa as thrust.

portional to the increase in absolute temperature of the turbojet mass-flow entering turbine fan.

You get in this case, the same amount of lift from a smaller fan, or a greater amount of lift from any given fan size.

What Progress? — Cursory investigations have been made on aircraft ranging from very small personnel carriers for high subsonic speeds through supersonic transports.

Supersonic aircraft as a matter of basic design require good area distribution, low profile drag, very thin wings, etc. Keeping good aerodynamic principles in mind, completely feasible designs have been made with fans submerged in wings with a thickness ratio of 4 per cent. Assuming reasonable efficiency and good stability during transition it seems entirely reasonable, then, that supersonic cruise type aircraft, either fighter-bomber or transport, can be designed around the Vertifan concept.

Hardware Not Built—Ryan designers say that they have been able to define a great many of the major parameters involved, through the use of wind tunnel test data. A considerable amount of information has been developed concerning the VTOL transition and STOL areas. Consideration has been paid to the rather large inherent ram drag characteristics of the Vertifan concept. The necessary techniques to achieve transition have been evolved. A good many of the aircraft control and stability requirements, in terms of the roll, pitch, and yaw moments incurred during transition have been determined. The hardware has yet to be built

A REPRINT
of this article can be obtained by writing on company letterhead to The Editor, AIRCRAFT & MISSILES Chestnut & 56th Sts., Phila, 39, Pa.

• HOW TO SELECT FAN SIZE

As an example of the factors which influence the size of the ducted fan, imagine this situation: (1) Aircraft with lift/drag ratio of 8 at cruise (thrust equal ⅛ gross weight), (2) Static thrust-to-weight ratio of 0.35 in turbojet powerplants, (3) Vertical lift requirement 20 per cent in excess of gross weight.

It would be necessary to increase static thrust of the turbojets 3 to 4 times in this case to get desired lift. The turbofan could do this. If the conversion takes place with an efficiency of η, we can write the following energy equation.

$$W_j \times \frac{v_j^2}{2g} \times \eta = W_F \times \frac{v_F^2}{2g}$$

and since

$$v_j = \frac{F_{slo}}{W_j} \times g \text{ (Momentum equation)}$$

and

$$v_F = \frac{L}{W_F} \times g$$

we find the ratio of fan mass flow to turbojet mass flow defined by the simple relationship,

$$\frac{W_F}{W_j} = \frac{L}{F_{slo}}^2 \times \frac{1}{\eta}$$

This means, that for a total efficiency of 70 per cent, we need a fan mass flow almost 17 times larger than turbojet mass flow. Thus, assuming that the frontal area per pound of air flow is approximately the same for both types of turbomachinery, we roughly estimate that the fan will have a frontal area 17 times that of the cruise jet engine or $A_F/A_j = 17$. To obtain an idea of the relative magnitude of fan area and wing area, the following estimate is useful.

We have already determined the ratio $F_{slo}/W_g = 0.35$. For cruise turbojets of the type considered, we can expect to obtain about 1400 lb thrust per sq ft frontal area or $F_{slo}/A_j = 1400$ lb.

Consequently, we find now the fan loading,

$$\frac{W_g}{A_F} = \frac{F_{slo}}{A_j} \times \frac{A_j}{A_F} \times \frac{W_g}{F_{slo}} = \frac{1400}{17 \times .35} = 235 \text{ lbs/sq ft.}$$

This should not be confused with the lift loading of the fan which in our case is 20 per cent higher, or:

$$\frac{L}{A_F} = \frac{L}{W_g} \times \frac{W_g}{A_F} = 1.2 \times 235 = 282 \text{ lbs/sq ft.}$$

With a fan loading of 235 lbs/sq ft, it is clear that, if we select a wing loading of $W_g/S = 47$ lbs/sq ft, our total fan area A_F must be 20 per cent of our wing area or,

$$\frac{A_F}{S} = \frac{W_g}{S} \times \frac{A_F}{W_g} = \frac{47}{235} = 0.20$$

If we now assume that 50 per cent of the total chord length can be made available for the installation of a lift fan, the geometric relationship shows that for the simplified case of a rectangular wing with 2 lift fans, only an aspect ratio b/c of about 2 is possible.

If a wing loading of 23.5 lbs/ft² is selected, an aspect ratio of 4 becomes possible. These examples illustrate the definite limitations in wing geometry which must be recognized.

If interburning is employed, T_{ft}/T_j can be introduced into the energy equation. It then becomes,

$$W_j \times \frac{v_j^2}{2g} \times \eta \times \frac{T_{ft}}{T_j} = W_F \times \frac{v_F^2}{2g}$$

and the mass flow ratio becomes,

$$\frac{W_F}{W_j} = \left(\frac{L}{F_{slo}}\right)^2 \times \frac{1}{\eta} \times \frac{T_j}{T_{ft}}$$

Using $T_{ft}/T_j = 1.2$ and $\eta = .70$ as before, the mass flow ratio and the corresponding area ratio become smaller by a factor of 1.2. The fan area now needs to be only about 14 times as large as the jet engine frontal area and our fan loading has gone up to 286 lbs/sq ft. This, in turn, would make it possible to decrease our wing area by a factor of 20 per cent, increasing the wing loading by the same factor. This change would probably improve the cruise L/D, if cruise speed is held constant, or it may result in increased cruising speed. In either case, range performance will improve. This advantage will have to be balanced against the increased hovering fuel consumption caused by interburning.

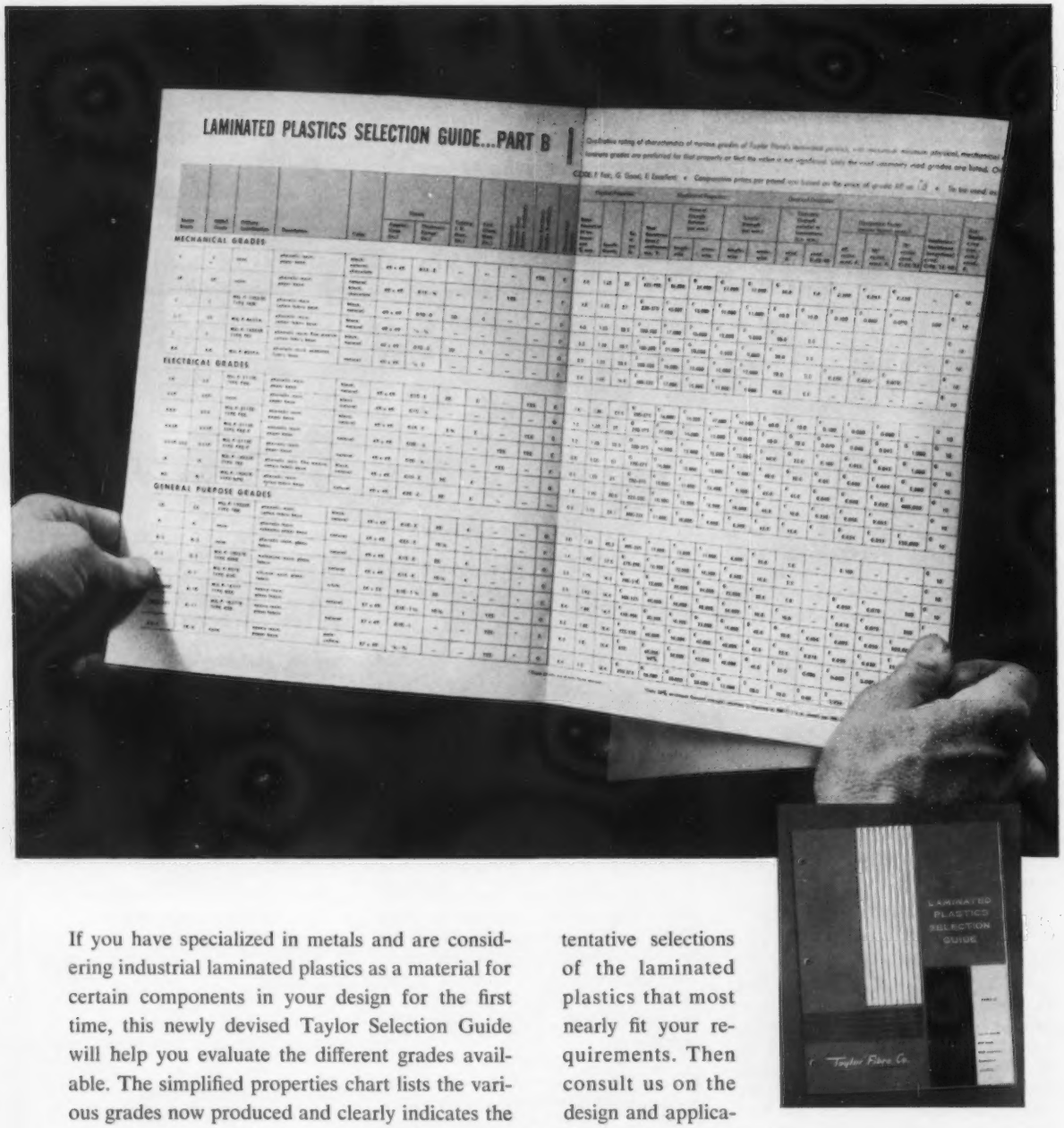
Symbols

- A_F Fan frontal area (ft²)
- A_j = Gas generator frontal area (ft²)
- F = Horizontal thrust (lbs)
- L = Vertical lift (lbs)
- S = Wing area (ft²)
- T_{ft} = Total gas temperature at fan turbine inlet (°R)
- T_j = Total gas generator exit temperature (°R)
- W_g = Gross weight (lbs)
- W_F = Fan mass flow (lbs/sec)
- W_j = Jet mass flow (lbs/sec)
- $_{slo}$ = Sea level static

From: The Ducted Fan in VTOL Aircraft Design, by Norman E. Nelson, Journal of AHS, Vol. 4, No. 1.

Important facts to know about laminated plastics

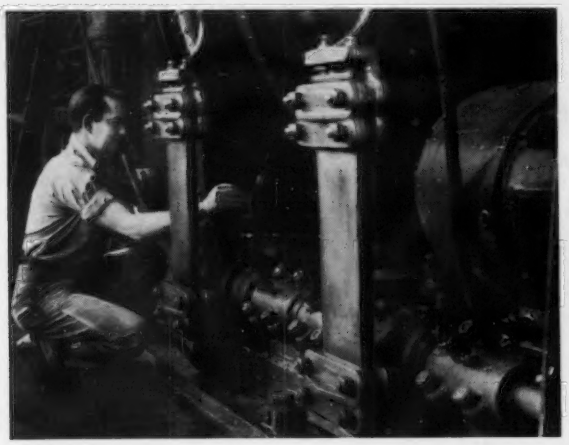
New Guide Developed by Taylor



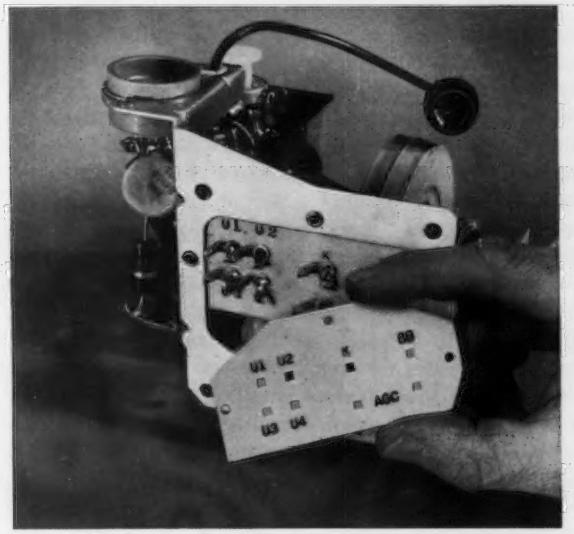
If you have specialized in metals and are considering industrial laminated plastics as a material for certain components in your design for the first time, this newly devised Taylor Selection Guide will help you evaluate the different grades available. The simplified properties chart lists the various grades now produced and clearly indicates the properties in which they excel. An accompanying booklet gives helpful hints on the selection of laminated plastics for your specific application. Write for your copy of this handy Taylor Laminated Plastics Selection Guide today. Use it to make tentative selections of the laminated plastics that most nearly fit your requirements. Then consult us on the design and application of laminated plastics and parts fabricated from them before making a final decision. Our application engineers will be glad to discuss them with you. Write Taylor Fibre Co., Norristown 50, Pa.

Simplifies Laminate Selection

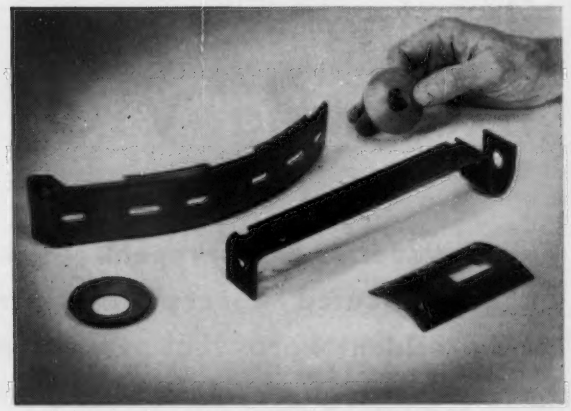
Suggested applications of different grades of Taylor Laminated Plastics



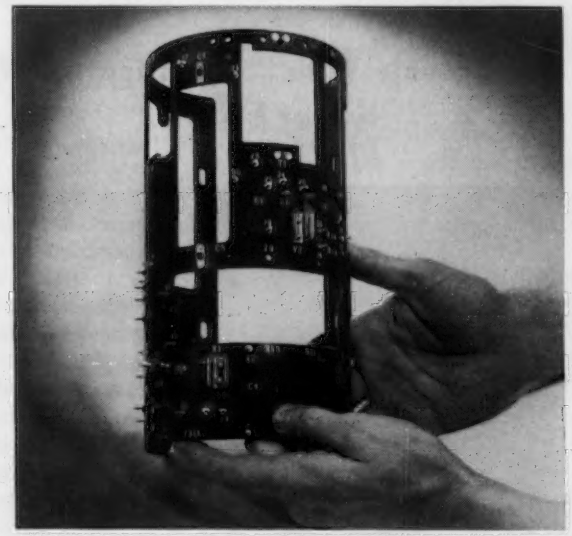
For the fabrication of springs, silent gears, pinions, cams and bearings: Taylor Grade C—a phenolic resin, cotton fabric base, mechanical grade and Taylor Grade L, a phenolic resin, fine weave cotton fabric base grade.



For high-temperature electrical applications and high-frequency radio equipment: Taylor Grade GSC—a silicone resin, glass fabric base, high-heat-resistant electro-mechanical grade.



For forming into intricate shapes, compound curves, and deep draws: Taylor Grade C-7—a phenolic resin, cotton fabric base, postforming grade. Also Taylor XX-7—a phenolic resin, paper-base postforming grade.



For applications requiring high-strength retention at elevated temperatures: Taylor Grade GEC—an epoxy resin, glass-fabric base grade.

Taylor

LAMINATED PLASTICS VULCANIZED FIBRE

Circle 18 on Inquiry Card

Helicopters vs. tilt-wing vs. "fixed-wing" VTOL's

Two engineering leaders speak out in defense of "sophisticated" concepts they pursue; AHS president warns that new schemes have lost basic advantage of "classic VTOL aircraft"

The Trouble With "Sophisticated" VTOL Aircraft

by Ralph P. Alex
President, American Helicopter Society

AHS Pres. Alex
flying barn doors

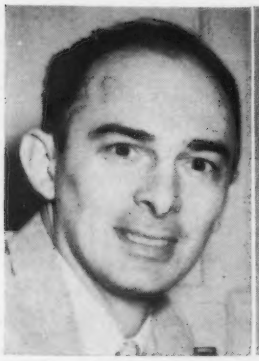
A large group of VTOL proponents feel the helicopter can be superseded by exotic methods of flight. These would provide vertical takeoff without the present limitations of forward speed suffered by the helicopter. Emphasis in this area has retarded an early breakthrough in substantial performance increases and design improvements of the helicopter.

Over the past several years a large amount of military R&D funding has produced varied types of VTOL's (tilt wing and ducted fan included). Most of these have provided successful flight test conclusions. But, none have been scheduled for service or production. All of these "sophisticated" types have shown one or several advantages over the pure helicopter. They have also lost the basic feature of the classic VTOL; that is, the ability to effect a safe landing in event of power failure. Another feature that suffers in comparison, is the great increase in power requirements and fuel consumption. In most cases these eliminate carrying little more than the crew and verbal messages in lieu of payload. The period of the "sophisticated" VTOL has truly proved that "given enough power, one can fly, or hover, a barn door." But, possibly people are not interested in flying a barn door.

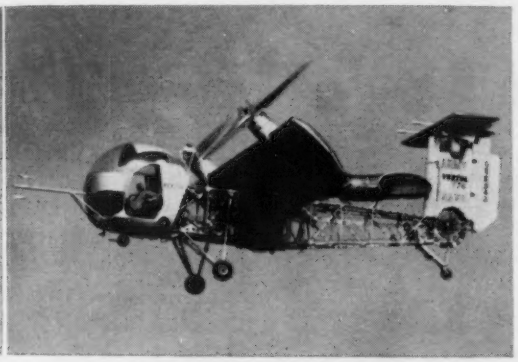
The tilt-wing concept has received much support. In projecting the production version, most analyses indicate a reasonable payload, with short to medium-range capabilities. Comparing this configuration with an average present turbine-powered fixed-wing transport and then adding the additional engines and power required, additional fuel and the necessary complications for conversion from VTOL to forward flight, the possible payload disappears almost completely. This indicated that, in order to meet the stated detail weights, great additional strides would be required in powerplant weights, structural design, and other areas far beyond the current state of the art.

Another point is in instrument flight: In this category the helicopter, with suitable navigation aids, has distinct advantages over the other type VTOL's which must depend on brute power for safe operating during this period.

In the overall concept there is certainly room for the "sophisticated" VTOL, where its advantages far outweigh its disadvantages. But, it should be awarded a figure of merit both from Research and Development and end use. The writer's opinion is that the helicopter is well qualified and capable of doing 90 per cent of the VTOL missions, and that the other types would be necessary for 10 per cent. The funds expended for progress should be in that proportion, and not the opposite as is the case at the present time.



Vertol's Dancik
the best of six



Vertol 76 (Army VZ-2)

The Case for the "Tilt-wing" VTOL

by Paul J. Dancik
R&D Engineer, Vertol Aircraft Corp.

During the past six years considerable effort has been given to VTOL/STOL aircraft capable of moderate subsonic speeds. For the military, operations from unprepared fields are foreseen; and, from a commercial standpoint, intercity transportation could be improved by operating aircraft from center-city locations. Another benefit derived from VTOL/STOL aircraft is increased safety. Approximately seventy-five percent of the airplane accidents occur either during takeoff or landing, and particularly during an approach for landing. High approach speeds are an important factor. With lower approach speeds, in the neighborhood ranging from 40 to zero mph, the pilot has more time to check his instruments, make proper control corrections, and effect a safe low kinetic energy landing.

Various types of VTOL/STOL aircraft have been suggested for an aircraft possessing these features. Vertol Aircraft Corp. concluded* that for a cruise speed ranging from 200 to 450 mph, the tilt wing concept appeared most promising. Vertol studied six basic airplane configurations: (1) deflected slip stream, (2) fan-in-wing, (3) deflected thrust, (4) tilting duct, (5) tilt-wing, (6) hover-jet. All of these aircraft have hover capabilities. However, for the same gross weight, the tilt wing VTOL/STOL aircraft requires the least horsepower.

To prove the feasibility of a tilt-wing aircraft, and confirm wind tunnel test and analytical studies regarding its feasibility, Vertol designed and manufactured in 11½ months, a tilt-wing research aircraft under a contract with the Office of Naval Research, for the U. S. Army. This aircraft, designated the Army VZ-2 (Vertol 76), is illustrated in conversion from hover flight to the airplane configuration.

Hover, airplane flight, STOL, and conversion flights have been demonstrated within nine flight hours. The ground and air flexibility of the VZ-2 makes the tilt wing a logical approach to the problem of moderate subsonic flight with safe low speed and short takeoff and landing characteristics.

Considering present technology, it is possible to design and build a VTOL/STOL aircraft which would have performance superior in many respects to conventional aircraft and helicopters. Studies and estimates show that the cost of VTOL/STOL need not be excessive. The tilt-wing fabrication costs should fall between the helicopter and airplane, yet provide hover capabilities with turbo-prop airplane cruise speeds. A commercial or transport tilt-wing would look no different than present day aircraft with the exception of possessing a smaller tilting wing.

Although the VZ-2 test bed utilized tail fans for directional and pitch control, they can be replaced by incorporating longitudinal monocyclic control in the rotor propellers to provide pitch control during the hover and conversion flight. Directional control would be effected by using differential ailerons in lieu of the directional fan. This eliminates the need for tail fans, or special thrust deflection devices in the fuselage aft end and places the entire control system in the rotor-props which are required. The rotors should be interconnected in the event of a power plant failure in one of the nacelles during hover or low speed flight.

A two-rotor prop tilt wing configuration would have an engine in each nacelle to drive each rotor prop. An interconnecting shaft would be unloaded during normal operation, however, in the event of a power plant failure the interconnecting shaft is there to drive the rotor prop which lost power thus providing symmetrical control. To design a four rotor-prop aircraft only a lateral extension of the existing wing interconnecting shaft is required.

The breakthrough has been made in the VTOL/STOL field and practical and operational aircraft can be available in the near future.

*W. J. Stepniewski, *"Tilt Wing Aircraft in Comparison with Other VTOL and STOL Systems,"* The Journal of the Helicopter Association of Great Britain, Dec. 1957.

Doak's Nelson
tilting ring-wings

Doak 16 (Army VZ-4DA)

The Case for the "Fixed-wing" VTOL

by Norman E. Nelson Chief Engineer
Doak Aircraft Co.

I was asked to present the case for the "Fixed Wing VTOL." However, considering the Doak 16 (Army VZ-4DA) as a fixed wing VTOL is not entirely correct; since, the tilting ducted fans are, in themselves, highly efficient ring wings. This makes the aircraft a combination fixed-wing, tilt-wing. It is correctly referred to as a tilting ducted-fan.

Doak's early analysis indicated that the ducted fan had many inherent advantages over the propeller, the rotor, and the turbo jet engine. Some of these advantages are:

(1) Ducted propellers show efficiencies approaching those of conventional propellers of larger diameter. Optimum fuel economy is therefore possible, especially when compared with turbo-jet engines.

(2) Ducted propellers are small in diameter and light in weight when compared with free air propellers.

(3) The small diameter permits the use of short landing gears and reduces the overall size of the aircraft.

(4) Ducted propellers exhibit excellent static thrust at all disc loadings. This permits the use of extremely small diameters when necessary due to configuration.

(5) Due to the small diameter, lower weight and lower hyroscopic forces, ducted propellers are relatively easy to rotate for conversion from vertical to horizontal flight, and return.

(6) Ducted propellers do not experience the adverse asymmetrical loading effects that conventional propellers exhibit in yawed attitudes, consequently, they are more adaptable to rotation from a vertical attitude to a horizontal attitude, and to steady operation at high intermediate angles of attack.

(7) The small diameter allows much higher rotational velocities, thus ducted propellers are more compatible with high RPM turbine power plants than are large slow turning conventional propellers. This high RPM leads to reduced shaft torque and reduced transmission weight and consequently a smaller and lighter aircraft than one employing a conventional propeller or a helicopter transmission and rotor.

(8) Lower propeller advance ratio variation is experienced by ducted propellers than with free air propellers in forward flight. Hence, the pitch change problem is less acute.

(9) The small-diameter ducted propeller which permits the use of a short landing gear also permits the design of an aircraft that takes-off and lands in a conventional manner when the ducts are aligned horizontally. It also allows the aircraft to make STOL type take-offs and landings with the ducts in intermediate positions. This is an important safety factor.

(10) The small diameter ducted propellers which permit the aircraft to be relatively normal in configuration permit the use of a relatively conventional control system. This alleviates the problems of pilot transition from normal flying to VTOL flying and eases the control system design problems, since considerable conventional aerodynamic theory and data can be utilized.

(11) The use of a fixed wing with ducted fans on the tips reduces the pitching moment in transition and adds to the safety of transition. The fixed wing operates unstalled throughout the entire flight range from hover through transition to high speed forward flight and return.

(12) Ducted propeller propulsion permits flight speeds higher than the best attained with the latest conventional propellers.

The ultimate design application of this type of propulsion would be in a VTOL/STOL aircraft which could utilize all of the advantages discussed above. A flight research prototype of such an aircraft has been designed, built, and tested under a U. S. Army Transportation Corps contract.

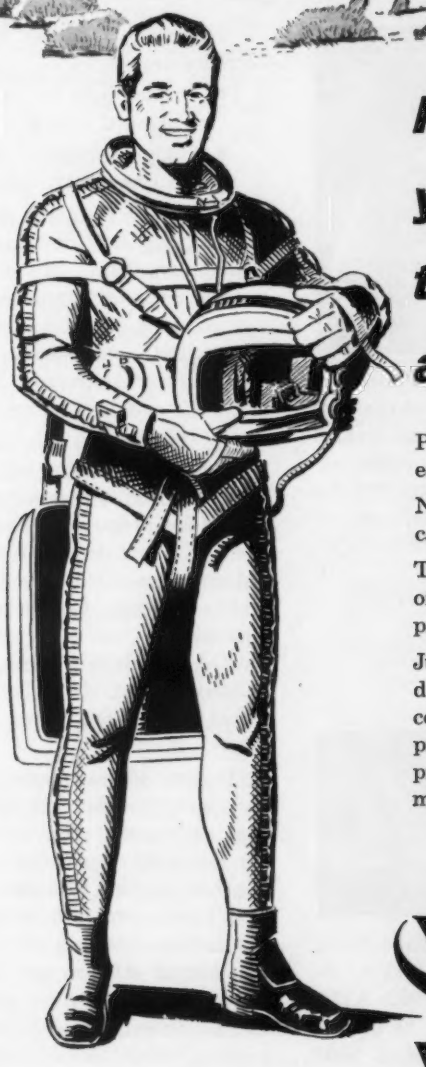
The aircraft has completed an extensive flight test program. Its success has assured the future of the "tilting ducted-fan VTOL/STOL aircraft."

✦

A REPRINT

of this article can be obtained by writing on company letterhead to The Editor, AIRCRAFT & MISSILES Chestnut & 56th Sts., Phila, 39, Pa.

V-R CREATING THE METALS THAT SHAPE THE FUTURE



Pioneering... yesterday... today... and tomorrow!

Pioneering is open in many fields as man stands on the edge of space.

New metals and materials must be created to help carry him safely into space and back.

The metallurgical research and production experience of V-R refractory metal specialists can serve your program by building metals to meet your specifications.

Just give us your requirements for heat resistance . . . dimensional stability . . . density . . . resistance to wear and corrosion. We may be able to help you solve some of your problems. Our metallurgical know-how and complete production facilities are working full time creating metals to help pioneer a brighter future.

V-R

VASCOLOY-RAMET®

894 MARKET STREET • WAUKEGAN, ILLINOIS

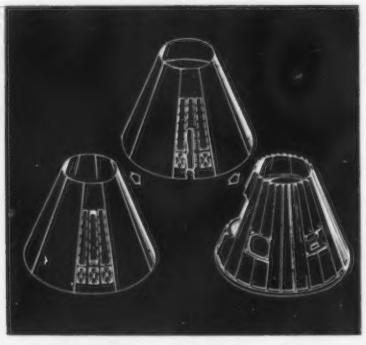
A-774

Design of Mercury Capsule and Systems

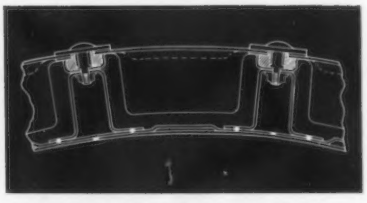
Shingled cobalt alloy over titanium pressure vessel and ablation heat shield are main structural elements; Systems have manual and automatic features which introduce necessary complexity

by M. A. Faget and R. O. Piland
National Aeronautics and Space Admin.

Fig. 1. CAPSULE DESIGN embodies outer skin of "shingled" cobalt alloy over a pressure vessel of twin titanium skins. Retro rockets and posigrade rockets are on blunt end. Escape rocket is mounted on tripod at opposite end. View ports are two layers of 96 percent silica glass over two layers of aluminosilicate glass.



PRESSURE VESSEL is made in three basic parts. Tapered titanium sheets are beaded, then butt welded to conical shape. Two cones are then joined by seam welding the beads. Stringers and doublers are then added by spot welding.



CROSS SECTION of capsule shows outer 0.0010-in. cobalt skin attached to pressure vessel with A286 nickel-base bolts. Layer of fibrous insulation slows heat passage. Spot and seam welds have been made with 13 to 1 thickness ratio at joint.

The basic objectives in Project Mercury are:

- Orbital flight and recovery of a manned vehicle.
- Studying man's capability in the space environment.

The intent from the outset has been to keep new developments to a minimum. Many of the Mercury systems, therefore, require only a logical extension of existing technology. But, since mission requirements and environment are quite severe, a certain amount of complexity is necessary.

A ballistic reentry vehicle will be used, with an existing ICBM booster for propulsion. Retro rockets will initiate descent from orbit, and parachutes will be used as a landing system. Complete escape capability for the pilot during the boosted portion of the mission will be incorporated, since the boosters cannot be counted on to be completely reliable.

Design Requirements — While undergoing the vibration, heat, gyration, and acceleration of entering and returning from orbit, the capsule must provide a livable environment for the astronaut inside. Communications between the capsule and ground stations are almost a must. The capsule must also operate as a fully automatic system for a number of flights before the pilot is introduced into the system. However, when the pilot does fly, he will

have the capability for controlling the flight. The pilot will add a great deal of reliability to the flight systems.

Capsule and Escape System—Fig. 1 shows the capsule and escape rocket configuration. The capsule reenters with the blunt end forward. This end is protected by a heat shield made of fiberglass reinforced plastic. On the afterbody, heat is dissipated by radiation. This portion of the capsule is covered with metal shingles made of cobalt alloy. The shingles are corrugated for stiffness, and are about 0.010-in. thick. Underneath the outer structure is a pressure vessel made of two thicknesses of 0.010-in. titanium. The pressure vessel is built to a spec which allows 500cc/min leakage.

The retro package is on the blunt end of the capsule. It contains the three retro-rocket motors and the three posigrade rocket motors. The posigrade motors, which are the smaller, are fired at burnout of the booster and are used to effect separation with a velocity increment of about 20 fps.

The retrograde motors are fired at 5 sec intervals to provide a velocity increment of about 500 fps for bringing the capsule out of orbit. Each retro rocket burns for about 10 sec. The firing of the retrograde motors is interlocked with an attitude gate of ±16 deg from the desired 34-deg nose-up, retrograde attitude. If the capsule attitude drifts out of this gate, the retro rockets will not fire. If one has fired, the sequence will be stopped until the attitude is corrected.

The escape rocket is mounted on a tripod which in turn is connected to the capsule by a Marmon band. This rocket has a large total impulse to rapidly provide separation of the capsule if the booster fails. If the failure is on the pad, the rocket will lift the capsule high enough to allow the parachute to open and return the capsule to Earth. During flight in the atmosphere, the capsule escape rocket has a sufficient thrust-to-drag margin to separate the capsule from the booster. By jettisoning the escape rocket and tower after Atlas staging, while the velocity is still relatively low, only a small penalty is paid for this rather heavy system.

Escape Initiation — There are several methods to initiate emergency escape from the booster. It can be done by the pilot, by the ground crew, or automatically by the booster itself. The pilot initiates an escape by twisting his left-hand grip. But, he can "eject" only after the Atlas has lifted a few inches. The test conductor in the blockhouse can initiate an escape at any time through a hard line to the booster. After lift off, an escape can be initiated through a command link. The booster itself automatically initiates an escape if trouble is sensed in any of the critical booster systems. Both the Atlas and Redstone boosters have abort-sensing systems. Both these systems are based on sensing the least number of quantities that will indicate impending failure of any type. Detailed analysis of past booster development problems show that the booster abort-sensing system will initiate an escape at least several seconds before a catastrophic failure.

Mission Sequence—The flight events during the Mercury-Atlas mission are controlled by a sequencer in the capsule. Fig. 2 shows important events for a normal mission, and the sequence of events that will take place in the case of an abort either before or after booster staging.

The middle column indicates the sequence for a normal mission. The mission is started by a firing signal from the blockhouse. But, the pilot must first indicate his readiness for the mission by closing a switch which lights the "pilot-ready light" in the blockhouse. Shortly after booster staging, the escape tower is jettisoned, its high impulse not being required for escape outside the sensible atmosphere. When

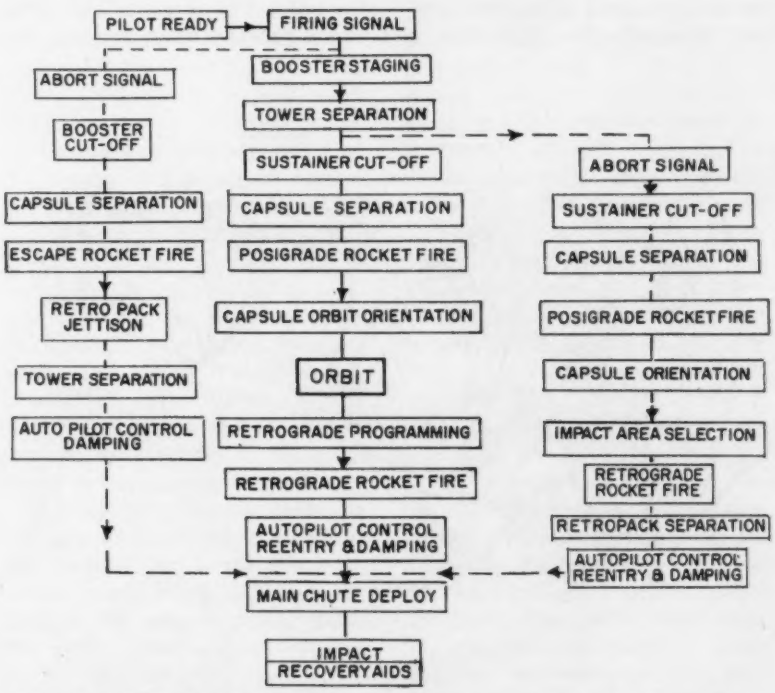


FIG. 2. MISSION SEQUENCE shows major events in Mercury flight. Middle column indicates normal mission. Left column shows abort prior to booster staging. Right column shows abort after booster staging.

Flight-attitude controlled by H_2O_2 thrust; Auto-system uses 2 attitude gyros, 3 rate gyros

orbital velocity is attained and the sustainer is cut off, the posigrade rockets are fired to separate the capsule. The capsule autopilot then controls the capsule attitude through a series of maneuvers terminating with reentry after the retro rockets are fired. These will be discussed in detail later. At 10,000 ft, the main parachute is deployed and upon impact, recovery aids are put into operation. The reserve parachute is used only in the event of main parachute failure.

The left-hand column shows the series of events which will occur when an abort is initiated prior to booster staging. This would be an abort employing the escape rocket. The right-hand column shows the sequence of events that would take place if the flight were aborted after booster staging, but prior to sustainer cutoff. In this type of abort, the impact area could extend over several thousand miles. Therefore, a desirable impact area is selected by range monitors and the flight is controlled by the time at which the retro rockets are fired.

The Satellite Clock—The events shown are only the major ones. They represent only a small portion of the actual number of events. Sequencing is carried out electrically by a combination of timers, sensors, and barostats. The most important of these is the retrograde firing timer, which is called the satellite clock. This timer is preset prior to launching, but may be corrected during orbit through radio command by the range monitors, or manually by the astronaut.

Environmental Control — The environmental control system provides the pilot with a suitable atmosphere and cools the equipment in the capsule. There are two control loops: the cabin circuit, and the suit circuit (Fig. 4). The cabin circuit provides cabin cooling. The suit circuit not only cools the air but removes odors, CO_2, and H_2O, and replenishes the oxygen that the pilot has used. While aloft, the Mercury astronaut breathes a pure oxygen atmosphere at 5 psi. He wears a full pressure suit which remains deflated unless there is a pressure failure in the cabin which is also kept at 5 psi. The face plate on the helmet is normally open and must be closed manually by the pilot in an emergency situation. In the suit circuit, odors are removed by an activated charcoal bed, the CO_2 is removed with lithium hydroxide, the air is cooled in the heat exchanger. Downstream of the heat exchanger water condensed from the air is caught with a vinyl sponge which is squeezed out periodically into a condensate container. Water is used as a coolant for both the suit and cabin.

Attitude Control System—Attitude of the capsule can be controlled either by a completely automatic system or by a manual system. H_2O_2 thrust chambers are used to provide correcting moments in both systems.

The auto pilot used for automatic control consists of two attitude gyros, three rate gyros, and logic and programming circuits. During the flight, the vertical gyro is erected by the infra-red horizon scanners. Erection is programmed every ten minutes. The vertical gyro is also constantly precessed in pitch to match capsule's rotation about Earth. The directional gyro is erected at the same time as the vertical gyro. This is done essentially by aligning the gyro axis to eliminate apparent precession due to yaw error as the capsule rotates in pitch as it circles Earth.

H_2O_2 thrust chambers used in the automatic system are controlled by solenoid valves. To conserve fuel, two sets of thrust chambers are needed. For pitch and yaw, 24-lb and 1-lb thrust units are used. For roll, 6-lb and 1-lb units are used.

The manual control system has another complete set of throttleable thrust chambers. These are rated at

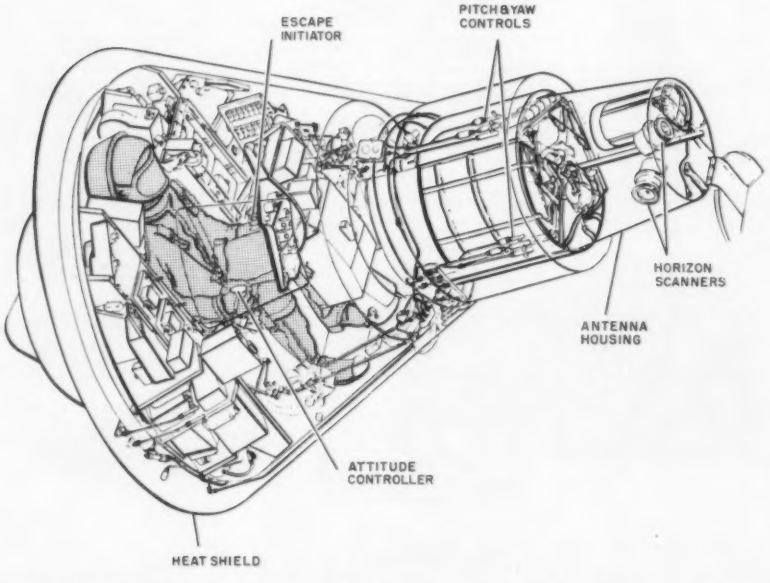


FIG. 3. INSIDE THE CAPSULE, the astronaut sits upright during orbit. Right hand grips attitude controller, left grips abort handle. Instrument panel and periscope are in front of him.

24-lb thrust for pitch and yaw and 6-lb thrust for roll. Each chamber can be operated either through a solenoid valve or a mechanical valve, depending on how the control system is being used. The primary method is a rate command system in which the pilot can, through his right-hand controller, command the rate of rotation in either of the three axes. In this system, the solenoid valves provide on-off control. Rate input is obtained from an additional set of rate gyros. In the event of an electrical failure, the pilot can operate the same control system directly, through mechanical linkages using the proportional mechanical valves. Analogue studies have shown that control through the mechanical systems will be much more difficult, particularly during retro-rocket firing when it is expected that large upsetting moments will develop. The pilot may, as a third alternative, control the thrust chambers of the automatic control system through electric switches on his controller. In this case, he would have neither proportional control or rate input.

Automatic Control System Modes — The automatic control system will be operated in various modes during an orbital flight. There is the orientation mode where either high and low torque thrust chambers will be used depending on the magnitude of error. If there is only a small error of attitude and rate, low torque thrust chambers are used. At greater errors, the high torque thrust chambers are activated.

In the retrograde mode only the high torque thrust chambers are used. They are activated at the same error which would have activated a low torque thrust chamber in the orientation mode. Thus, the retrograde mode provides a much tighter control which is necessary to overcome the upsetting moments of the retrograde rockets.

In the orbit mode, a different type of control logic is used and only attitude sensing is required. In this case, small calibrated pulses

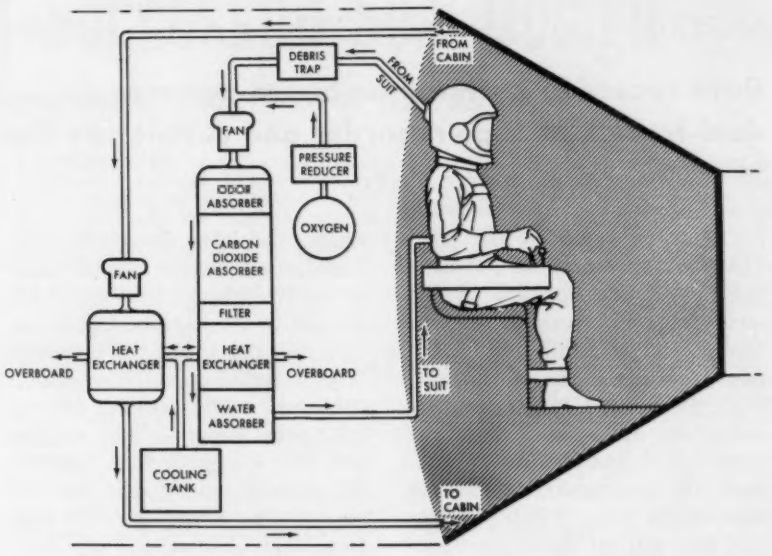


FIG. 4. ENVIRONMENT CONTROL system gives pilot livable atmosphere and cools equipment in the capsule. System has two circuits: suit, and cabin. Pilot's face plate is normally open.

of thrust are used. This results in a long-period, lazy motion which will conserve the hydrogen peroxide propellant.

The damping mode is the same as the orientation mode except that the attitude sensing is cut out. During a normal mission, the automatic control system will be sequenced as follows:

Immediately after separation of the booster, the automatic control system is in the damping mode for a period of about 5 sec. Then it is shifted to the orientation mode while the capsule is rotated 180 deg in yaw and is pitched up 34 deg into the retro-rocket firing attitude. The capsule remains in this attitude for a period of about 5 min. This is done so that the rockets may be fired quickly in the event range monitors sense that the capsule is not in a suitable orbit. At the end of this time, the capsule will be reoriented to the orbital attitude which is 14 deg nose up. This is the attitude which places the pilot's periscope axis normal to the Earth.

After the capsule settles into the orbital attitude, the automatic control system is shifted to the orbit mode and remains in this mode until it is time for retrograde maneuver. At this time, the attitude control system shifts to the orientation mode and reorients the capsule to the 34-deg nose-up retrograde attitude. It is then shifted to the retrograde mode while the retrograde rockets are fired. It is shifted again into the orientation mode, and reorients the capsule to the reentry attitude which is 1½ deg nose down. It remains in the orientation mode until entry into the atmosphere is sensed by a 1/20th g acceleration switch. The automatic control system is then shifted into the damping mode and remains in the damping mode until the main parachute is deployed. At this time, the remaining hydrogen peroxide is jettisoned through the pitch and yaw thrust chambers.

Communication System — The various communication systems carried on the Mercury capsule are outlined in Fig. 5. Both UHF and HF frequencies are used for voice communications. These voice links are operated simultaneously. There are also two telemetry links, both in the UHF band, but one at a higher frequency than the other. As a backup to the voice communication, the high frequency telemetry

Data recorded by three on-board cameras, dual-track 8-hr tape recorder and cosmic ray film

link may be keyed by the pilot. There are two identical command receivers, both operating on the same frequency, carried on the Mercury capsule through which three functions may be initiated from the ground. These are, resetting the retro-timer, firing the retro-rockets, and aborting the mission. The command receivers can also receive voice communications and this will be done simultaneously with the UHF and HF links when the capsule is in range of the command transmitter.

FIG. 5. COMMUNICATIONS SYSTEM

I. TWO-WAY UHF VOICE
II. TWO-WAY HF VOICE
III. TELEMETRY (UHF)
  A. HIGH-FREQUENCY—MAY BE KEYED BY PILOT
  B. LOW-FREQUENCY
IV. TWO COMMAND RECEIVERS (GROUND TO CAPSULE VOICE CAPABILITY)
V. C-BAND RADAR
VI. S-BAND RADAR
VII. RECOVERY BEACON—UHF/VHF (SARAH/SEASAVE)
VIII. EMERGENCY UHF/HF TWO-WAY VOICE

The Mercury network uses both C-band and S-band radars and consequently both C and S-band radar beacons are carried aboard the capsule. As an aid to search and recovery, a combination of the SARAH and SEA-SAVE beacon is carried on the capsule and is activated after the main parachute is deployed. In addition to the above equipment, there is a completely separate emergency two-way voice system of UHF and HF transceivers

While in orbit, all communication links with the exception of the radar beacons, are multiplexed onto a common discone antenna, located in the truncated cone at the rear of the capsule. This portion of the capsule, called the antenna section, is jettisoned at deployment of the parachute. After the parachute opens, the UHF links are transferred to a monopole antenna which is directly in back of the cylindrical portion of the capsule. Upon contact with the water, the parachute is jettisoned and an HF antenna is deployed by a helium-filled balloon.

Power Supply — The capsule gets electrical power from batteries. AC is produced by solid state inverters. The battery power comes from three batteries. There is a main battery, and an auxiliary battery which is isolated from the main battery. These two batteries are backed up by a standby battery which is switched in automatically if either of the other two fail. There is also a standby inverter which is automatically switched in, if either of the regular inverters should fail.

Measurements — The types of measurements which will be made during the orbital and ballistic flights of the capsule are listed below. These measurements will be telemetered to ground tracking stations and also recorded aboard the capsule by a tape recorder. The purpose of most of these measurements is self evident. In the areomedical area the pilot's EKG, his respiration rate and depth, and his deep-body temperature will be measured.

MEASUREMENT BY INSTRUMENTATION

1. AEROMEDICAL DATA
2. SEQUENCE OF EVENTS
3. CONTROL EVENTS
4. CAPSULE ATTITUDE
5. VOICE COMMUNICATIONS—EVALUATION
6. SATELLITE CLOCK—MONITORING
7. TEMPERATURES
8. PRESSURES
9. ACCELERATIONS
10. SOUND LEVEL AND VIBRATION LEVEL
11. POWER SUPPLY

On the unmanned flights, the voice communication system will be evaluated by transmitting a prerecorded tape from capsule to ground stations and at the same time recording on tape in the capsule, ground-to-space transmissions.

Monitoring the satellite clock, which fires the retro-rockets, is particularly critical piece of information which must be precisely telemetered to the range stations. Since it may be necessary to change the setting of the retro-firing time by radio command during the flight, ground stations must have the capability of monitoring the satellite clock.

Cameras and Recording—The cameras and on-board recording equipment used in the capsule will be: (1) two 16-mm cameras, which photograph the pilot and the instrument panel. (2) one 70-mm camera, to photograph the horizon through one of the capsule windows. These cameras will not only film the view from the capsule, but will provide useful information on the status of the on-board equipment, the condition of the pilot and the motions of the capsule during the mission. There will be a two-track, 8-hr tape recorder in the capsule to record various measurements made during the flight. Finally, there will be several cosmic ray film packs located near the pilot's head. These emulsion packages will record intensity and the direction of cosmic rays encountered during the orbit.

Air Cushion For Impact—The capsule will land on an air cushion formed by a four-foot skirt of rubberized-fiberglass that connects the heat shield and the rest of the capsule. After the main parachute is deployed, the heat shield is released from the capsule, drops the length of the four-foot skirt, and the bag fills with air. Upon impact, the air trapped between the heat shield and the capsule is vented through holes in the skirt and the portions of the capsule which are not air tight. The desired cushioning effect is thus achieved.

✦

A REPRINT

of this article can be obtained by writing on company letterhead to The Editor, AIRCRAFT & MISSILES Chestnut & 56th Sts., Phila, 39, Pa.

Secrets of Successful Seal Design

Fundamentals — No. 1 of A Series

SPACE — Around Sealol the bane of our existence is the job which comes to us designed in toto — "no changes allowed. Please fit your mechanical seal into this space". If there isn't space enough, the solution will usually be a compromise with performance standards sacrificed. As an example, a 1" diameter shaft will require a standard Sealol seal with a .531" operating range and a mating ring preferably .250" for a total of .781". This particular seal allows .020" for tolerance stack-up and shaft end motion. But suppose you have allowed us only .700" with a stack-up tolerance of .040"? We may be able to reduce the space required for the seal without sacrificing performance but only if the stack-up tolerance can be reduced to .020". In some cases selective assembly or shimming can produce satisfactory operating life with a bare minimum of axial space. ***Moral*** — *Send us your design before it is frozen.*

P.S. Diametrical space requirements do not bother us, but we do urge you to take into account the relative co-efficient of expansion of the stainless steel cup of our seal and the material into which you want it assembled. Sealol's Bulletin #7, Page 6, has some charts which may be helpful.

CHARACTERISTICS — In the old days, say ten years ago, you could spot an industrial seal application as distinguished from an aircraft high-performance type of application, a mile away. The former provided for rotation of the axial movable part — the latter invariably provided for these axial movable parts to be stationary in respect to the shaft. Times have changed, but designers generally favor the stationary seal where overall axial space is at a premium since it requires only 40 to 70 percent of the space of a rotary seal. Naturally, they are also much lighter. Furthermore, when shafts start turning at speeds beyond 5000 RPM, springs, pins and assorted hardware have a way of losing their functional abilities and for these situations, the stationary seal is mandatory. On the other hand, rotating seals are usually more rugged in their construction, and they are self-cleaning. They are used extensively on industrial pumps, blowers and compressors. We don't propose to be too dogmatic about the small table shown below, but it serves to delineate our present parameters for stationary and rotating seals.

MAXIMUM OPERATING CONDITIONS

	Stationary Seal	Rotating Seal
Shaft Speed	100,000 RPM — 1/4" Dia.	5,000 RPM to 3" Dia.
Temp.	—425° to + 1000°F	—60° to +450°F
Pressure	2,000 psi	1,200 psi

Note: Maximum conditions indicated do not mean that all are available in a single seal.

Viton-A and Teflon are registered trademarks of E. I. du Pont de Nemours & Co., Inc.

PRESSURE — One of the most critical conditions, but one of the most inconsistent, is pressure. Many the time there has been much Sealol head-scratching over a 2 lb. pressure differential in one test rig, whereas pressures in excess of 2000 lbs. were being handled in routine fashion in an adjoining rig. We would be delighted to exchange data with you on pressure phenomena, but in the meantime, you may be interested in the following tidbits. Since operating life of a seal is a function of face load, pressure considerations can be really critical. We design to a unit face-load usually of 8 to 40 psi. depending, of course, on the spring and area involved. Hydraulic pressure of the fluid being sealed and the fluid film pressure across the seal face must also be reckoned with. Around our premises, our engineers banter back and forth a semantic generality called 'seal balance'. If you are interested, ask us for NCIH Paper "Factors in Designing for Mechanical Seal Applications to Hydraulic Equipment". Seal size has a considerable bearing on pressure capability, and as shaft diameters go up into sizes, say above 12 inches and pressures go to 500 psi, seal ring sections become quite massive to prevent distortion. Incidentally, 100 psi is about the maximum pressure we recommend for an unbalanced seal. For higher pressures, we must reckon with interface film destruction resulting from non-balanced face loads.

SHAFT SPEED — Top-flight designers are certainly stretching seal performance in many ways. Not the least is your incredible ability to cram into minute space great horsepower performance. This is meaningful to us, because the shaft speeds you now call for are exceeding, in many instances, speeds of 50,000 RPM. Of course, a 100,000 RPM — ½" shaft is probably within the capability of existing seals, but from a seal standpoint, the relative surface speed of the seal faces should not exceed about 18,000 FPM under ideal conditions. Irrespective of face materials, this seems about maximum for full contact and leakproof sealing today.

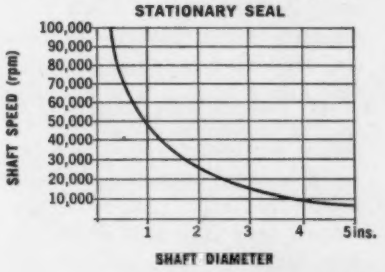
TEMPERATURE — As seal designers, our temperature goes up when you ask us for high performance beyond 450°F. ambient. This is about the usable limit for today's elastomers, such as Viton-A and Teflon. However, this too may be misleading. There are Sealol-Flexibox elastomeric packed seals doing a beautiful job in oil refineries with pump temperatures of 750°F. The secret here is, of course, controlled temperature at the seal to produce seal ambients below 450°F. However, within the last two years, Sealol's welded bellows seals are performing well at temperatures to 1000°F. Our thought for the day — if it can't be cooled to within elastomeric limits — consider the all metal welded bellows seal.

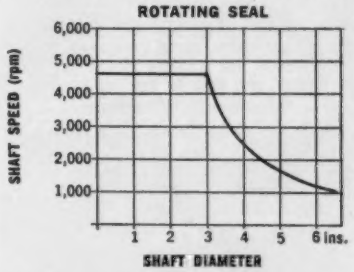
MOUNTING ARRANGEMENT — If possible, the fluid being sealed should be on the O.D. of the sealing faces. Centrifugal force of any fluid between the faces will then work in your favor to prevent seepage between the rubbing faces. Seals can function satisfactorily with fluid on the inside of the seal faces. We can both avoid long hours on the assembly line later looking for leaks if we arrange matters so that the fluid is on the outside of the face.

RUN OUT — We've heard many definitions of run out, but here is ours: The deviation of the plane of the rotating ring from a plane perpendicular to the axis of the shaft. It usually results from a lack of squareness of the rotating sealing surface to the axis of rotation. It causes a wobble of the ring and tends to bounce the seal ring away from contact at high rubbing speeds. For a 2" shaft at 20,000 RPM, run out should not exceed .0005" at the point of contact.

If these thoughts have aroused your interest, write to us with your questions, and we will be glad to elaborate.

The following tables define maximum shaft speeds under optimum conditions.





SEALOL CORP.

424 Post Road, Providence 5, R. I.

Providence — Stuart 1-4700
New York — Whitehall 3-9748
Phil. — Tremont 2-2226
Chicago — Independence 3-6707
Denver — Florida 5-7260

Cleveland — Washington 1-7234
Dayton — Axminster 8-3009
Houston — Greenwood 2-2318
Los Angeles — Chapman 5-3746
San Francisco — Yukon 2-0800

In England: Flexibox Ltd., Manchester
In Europe: Flexibox S.A., 38 Rue de Trevisse, Paris 9
Flexibox G.m.b.H. Schielestrass 45, Frankfurt/Main-Ost

Design Considerations for GEM's

Basic problem of Ground Effect Machine is to maintain static cushion pressure between itself and the ground; "Classical" configuration still being sought; Development may be spurred by military applications

by Eugene K. Liberatore
GEM Research Engineer

BASIC GEM CONFIGURATIONS

The ground effect machine, (GEM) is a vehicle that operates on a cushion of air, at heights only a fraction of the cushion's maximum dimension. GEM's are generally of circular planform, and this "height-diameter" ratio h/D is a significant parameter in understanding their behavior; it influences performance and stability.

An air cushion is provided by static pressure between the vehicle base and the ground. Since this air can escape around the sides, a peripheral air-seal is required. Physical walls would provide a good sealing system, but would also impede forward flight. Thus, the basic problem of the GEM is to maintain static cushion pressure with the least expenditure of power. One simple solution is to discharge air from a plenum into the atmosphere. Air is compressed by a fan, and discharged through a peripheral sharp-edged exit. Sharp edge provides a vena contracta which permits GEM to hover at a height about 60 per cent greater than it would with a flat-based exit. Design of the plenum is important, because some configurations create a suction rather than a pressure.

A second type of seal uses a peripheral jet of air. In this approach, base pressure is contained by the impact force of the jet as it is deflected inward, plus the reaction force of the jet as it is discharged outward along the ground.

A third configuration utilizes the labyrinth seal principle (similar to the steam turbine application) to generate a turbulent static-pressure region surrounding the cushion static pressure. This system recirculates air to reduce total power required; here, more than one stage is generally required. Recirculating fans are usually located on the periphery of the GEM. The labyrinth-seal type is associated primarily with large ocean-going GEM's.

A fourth variation is the air-bearing type GEM. This differs from the others in that it uses a smooth surface, or rail, and an air boundary layer 0.005 to 0.015 in. thick; positive static pressure is provided by viscous effects within boundary layer of discharging air.

Other approaches to sealing the air cushion are: liquid jets, physical walls, ram diffusion, ejectors, etc.

Although the four types of GEM described have received the most attention, there are additional promising systems. In the history of the GEM, morphology plays an important part; "classical" configurations are still being sought. We

need to know what shapes or structural elements will provide the best cushion-sealing system, and which combinations of known propulsion systems, compressors, controls, hulls, ducting, etc., are optimum.

Environment apparently influences GEM evolution, because ship-oriented investigators differ in their approach from aircraft-oriented investigators.

Annular-jet and plenum-chamber GEM's are emphasized here, because more is known about them. Other systems may be just as good or better. For example, the labyrinth-seal type, for equal size, weight, and operating height, can hover on about half the power required of the annular jet. The price for this gain is complexity of the air-moving system. Other types that have special features to minimize the amount of air taken on board, in forward flight, will also show up better than the conventional annular jet. Comparing the annular jet with the plenum type, it can be seen the latter is simpler, but the annular-jet type is capable of hovering out of ground effect. This is accomplished at a greater cost in power (or fuel rate) than for a jet without a base plate. Out of ground effect, the base plate produces a suction subtracting from the momentum thrust. This suction can be minimized by modifying the base contours.

Performance — Engineering theory of the annular jet has been developed further than that of other systems. In the U. S., this work has been done by Dr. H. Chaplin of DTMB and Dr. G. Boehler of the Aerophisics Co. In England, the theory has been developed by Crewe, Eggington, and Stanton-Jones.

In determining hovering performance of the annular jet, the first and fundamental question to ask is this: Ideally, how much total pressure Pt_j (Fig. 1) in the nozzle (hence, how much power) is required to produce a given amount of cushion pressure Δp_b? A simple relation is established using momentum theory for the two-dimensional case (i.e. per unit of circumference) which equates the static pressure force $\Delta p_b h$ to the force of the jet. F_j. This force has two components parallel to the ground. The first comes from $F_j \cos \theta$ as the jet is injected inward, and the second is the reaction force F_j as the flow (ideally) escapes outward along the ground.

Thus: $\Delta p_b h = F_j (1 + \cos \theta) = \rho t v; (1 + \cos \theta)$ ρ = air density.

The total pressure in the jet

$$Pt_j = \tfrac{1}{2} \rho v_j^2 + \Delta p_e, \text{ where } \Delta p_e$$

is the static "back pressure" on the jet. In a first approximation, it can be neglected, or if $h \geq t$ $\Delta p_e = \tfrac{1}{2} \Delta p_b$. These equations give the desired ideal pressure ratio.

$$\frac{\Delta p_b}{Pt_j} = \frac{2 (1 + \cos \theta)}{h/t + (1 + \cos \theta)}$$

Thus, height-thickness ratio and jet angle are the significant parameters. Note that in the above equation the independent variables are two-dimensional. For a given area, the perimeter that gives the shortest length of $\frac{h}{t}$ will give the least hovering power. Thus a circular planform will give the lowest hovering power. For a high-speed GEM, or from other considerations another planform may be more desirable. The equation is plotted in Fig. 2. The ratio $\frac{\Delta p_b}{Pt_j}$ is in effect an "efficiency," since it shows how much of the total pressure Pt_j in the jet is converted to stagnation or static pressure Δp_b. The ratio can never be greater than 1.0. For the ideal plenum chamber, the base pressure equals the dynamic pressure of discharge, or:

$$\Delta p_b = \tfrac{1}{2} \rho v_j^2 = Pt_j$$

Thus:

$$\frac{\Delta p_b}{Pt_j} = 1.0$$

Fig. 2 suggests that the annular jet approaches the plenum chamber condition when $\frac{h}{t}$ is near 1.0. The total pressure Pt_j determines the ideal air horsepower at the annular nozzle.

$$A H P = \frac{Pt_j Q_j}{550}$$

Q_j = Vol Flow through the nozzle. (cfs)

In a practical design, there are many losses, including a nozzle loss, duct loss, compressor loss, gear loss, etc. To obtain an approximate value for the shaft power required BHP_s, an empirical equation given in Reference 2 can be used. The equation applies to either the annular-jet or plenum-chamber type.

In this discussion, the "diameter" D is the actual diameter to the outer edge of the jet of a circular planform GEM or the equivalent diameter of a non-circular type that will give the actual area. For sea level standard conditions:

$$MF = 33.8 \left[\frac{PL \sqrt{DL}}{38} \right] \frac{h}{D} = \frac{\frac{h W_g^{3/2}}{D^2}}{B H P_s}$$

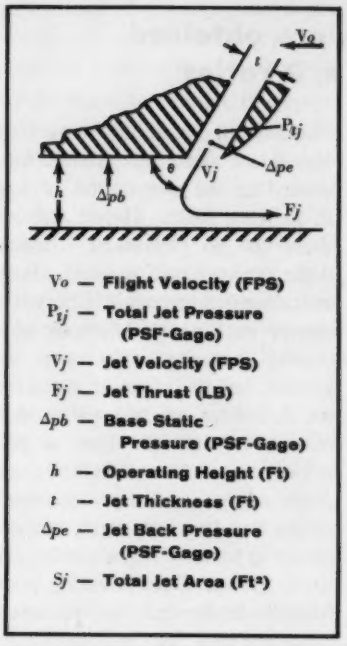
$$PL = \frac{W_g}{BHP_s} = \text{Power loading (lb/hp)}$$

$$DL = \frac{W_g}{S_t} = \text{"Disk" loading (lb/ft}^2\text{)}$$

In GEM theory, the total area $S_t = S_b + S_j$, the sum of the base area and the jet area.

continued on next page

Fig. 1 ANNULAR-JET NOTATION



Maximum power loadings are obtained at low disk-loadings and h/D ratios

D = Diameter or equivalent diameter

$$= \sqrt{\frac{4}{\pi} S_t}$$

The parameter M_f is called the "Factor of Merit." The term in the bracket is the same as the "Figure of Merit" defined for helicopter rotors. A practical value of M_f = 4.0, and it refers to a well-designed GEM. (GEM reduced models built without too much engineering behind them usually have a $M_f \cong 1.0$.) If the maximum hovering height is used for h, the equation gives the maximum hovering shaft power required, BHP_s. Note also that

$$BHP_s = \frac{AHP}{\eta} \qquad \text{where } \eta$$

is an overall efficiency factor < 1.0; Fig. 3 is a plot of the equation. The figure shows the maximum power loadings are obtained at low values of disk loading and low values of height-diameter ratios. As an example, consider a desirable power loading of 100 lb/hp. For a reasonable disk loading of 30 psf, the value of h/D must be 0.008. If the machine is to hover at one foot, it must have a 125-ft diam. This example shows a fundamental problem of the GEM. Practical GEM's can be designed by a trade-off of the important parameters of Fig. 3. For the annular jet GEM, the weight is supported by three forces: base-pressure force ($\Delta p_b S_b$), force due to back pressure on the nozzle ($\Delta p_e S_j$), and jet momentoum force ($\rho S_j V_j^2$). As the GEM operates closer to ground, base-pressure force dominates. Completely out of ground effect, only the jet momentum force is available to support vehicle.

In forward flight, the principal power losses are: cushion-power loss (as in hovering) momentum-drag loss (PS_jV_j) V_o, and parasite-drag loss (the last term is also called "profile" drag if the body is viewed as a "wing" rather than a "fuselage"). Presently there is disagreement as to what should be included in the summation of losses in forward flight. Hence, presently there is no "classical" forward-flight performance method. Representative power-required curves are shown in Fig. 4. Methods of reducing parasite drag are well-known, but the effect of air cushion on this drag has yet to be determined. Momentum drag, or product of mass flow and flight velocity, plays a large part in power requirements for forward flight. Cushion power in forward flight will be equal to, or greater than, hovering power. Magnitude depends on parameters such as $\left(\frac{V_j}{V_o}\right)$ which is the ratio of jet velocity to flight velocity, and ratio of height to jet thickness $\left(\frac{t}{h}\right)$ Visual flow tests in France by ONERA show an interesting transition in the flow pattern around a GEM (Fig. 5). Below a critical speed, the jet flow circulates up and over the machine (Fig. 5A). Above this speed, the jet is swept away (Fig. 5B). The latter condition is identified as the "jet-flap condition." The ONERA tests also showed that for low values of h/D, the space between the jets was completely filled with two vortices rotating in opposite directions.

Stability—A basic characteristic of the hovering GEM at a given power-setting is the thrust increase with a decrease in height. For the given setting, the associated hovering height is the only one at which the vehicle is in vertical equilibrium. Stability-wise, the GEM is statically and dynamically stable in the vertical hovering mode. Damping in this mode is heavy, and oscillations subside in less than two cycles. In some annular-jet designs, advantage is taken of vertical-mode stability to provide pitch-roll stability. This is done by compartmentation of base, so that it has a peripheral jet as well as two or more additional diametral jets, thereby dividing the base into "pie cuts." The GEM base is thus divided into four or more smaller areas, each bounded by a jet. In this manner, pitch and roll stability can be achieved. Another approach to using vertical mode stability is to design a machine using three or more annular-jet units mounted apart from one another. In one design, these units were also made tiltable for propulsion and control.

In general, GEM inherent stability is a function of height—diameter ratio h/D. A given GEM out of ground effect (like a turbo jet) is not stable. Hovering stability can

Fig. 2 JET PRESSURE vs BASE PRESSURE
(Annular Jet in Hovering)

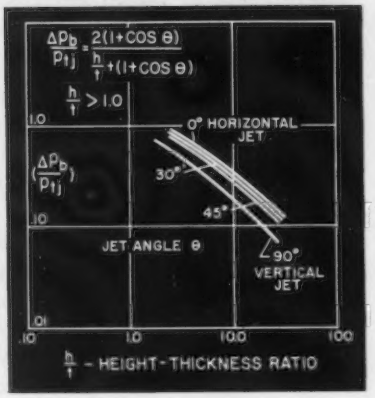
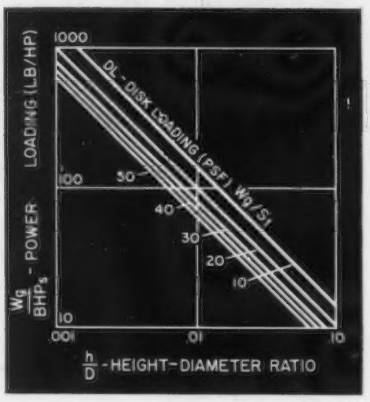


Fig. 3 HOVERING PERFORMANCE
(Annular Jet or Plenum Chamber, Std Sea-Level condition; M_F = 4.0)



be correlated roughly with h/D. Vehicles with a h/D of about 0.05, and preferably less, are inherently stable. The neutral-stability regime is around h/D = 0.08. Above an h/D = 0.13, the conventional GEM is unstable even with base compartmentation.

Saunders-Roe theory shows the single-ring annular jet is stable up to a height equal to the jet thickness, i.e. $\frac{h}{t} = 1.0$. Planform will also affect stability; elongated GEM's will not have the same stability characteristics in the pitch and roll modes. From this viewpoint, circular or square planforms are preferred. However, considering forward-flight performance, elongated or other planform shapes may be better.

An excitation unique to GEM's pertains to surfaces over which they operate. An ideal sinusoidal surface can create oscillations in forward flight, and these depend on relation between wave length and length of GEM. Relatively large waves can be driven like hills and valleys. Smaller ones are more troublesome. The vertical mode undamped natural frequency Ω_n is analogous to that of a simple pendulum.

$$\Omega_n = \frac{1}{2\pi}\sqrt{\frac{32.2}{h}}$$

Control — GEM control must consider propulsion, braking, yaw, and side-force control. These controls can be achieved by air jets, propellers, slipstream vanes, or by devices for inclining the machine. The brake can be the reverse of propulsion control. A stop also can be made by skidding or rolling on the ground.

In high-speed turns, a yaw is not necessarily accomplished with a bank. The GEM operates too close to the ground for this. Any circular GEM is unlikely to be free to bank more than six degrees, before a side would strike the ground. Skidding tendency in a turn may be countered by a side-force control system. However the side force can be very high. A typical turn without bank of "automotive proportions" would result in a side force about 20 per cent of the weight, and it could be as high as 100 per cent.

Over-Water Effects—GEM operation over water is not the same as operation over ground. In hovering over water, the base pressure creates a trough under the GEM, the depth of which in inches of water is equal to the base pressure. As the GEM moves forward, this trough moves ahead so that the machine assumes a nose-up attitude in an attempt to ride over the edge of the trough. The inclination introduces a weight component to the drag, increasing the propulsive power required. At a certain speed, this power is the greatest. The GEM must have sufficient power to exceed this "hump" speed. Once beyond the "hump" speed, inclination diminishes and the associated power requirements become negligible. For small or large GEM's this "hump" speed will be 10 to 20 knots.

Problems — Although there is sufficient knowledge to produce useful GEM's there are still problems of analytical, design, and operational nature. The hovering performance for annular jets and plenum-chamber configurations is fairly well understood analytically. Less is known about empirical stability derivatives. The structural aspects, and their relation to tolerable weights, have yet to be defined, especially for large machines.

The Office of Naval Research is sponsoring coordinated programs to cover gaps in GEM knowledge. Participating firms include: Bell, Hiller, Ryan, Lockheed, Vehicle Research Co., Aerophysics Co., and AiResearch. Other organizations participating include DTMB, BuShips, and University of Wichita.

Other problems associated with GEM's are listed below:

Powerplants — The largest GEM's will require 200,000 to 400,000 hp powerplants. Large aircraft gas turbines would need marine engine reliability, particularly if used in multiples. Due to the large amount of air handled by a GEM, a jet pump may be preferable to a shaft turbine. In the largest sizes, a nuclear powerplant may be the answer. For a giant transoceanic GEM, a powerplant plus fuel and fuel system weight of 20 lb per shaft hp or less would be highly desirable. This weight would not include the compressor, ducting, or drive system.

Structures — Acceptable design criteria, maximum allowable deflections, and reasonable weights are some of the considerations in this area. These are complicated by the fact that the GEM size range and environmental conditions are so wide. A particular problem of interest is the strength-weight relations of GEM hulls which must strike or clear waves.

Cushion and Momentum Power —GEM hovering-power requirement are directly proportional to height. At present, the minimum acceptable heights over land and water result in power requirements that are higher than most are willing to accept. This is aggravated by the forward flight momentum losses. Therefore, solutions are being sought to minimize these losses. Some of the devices being studied include sidewalls, or catamaran hull, over water, with the sides just clearing the water; secondary fluid jets to augment the cushion sealing; other cushion seals besides simple air jets; propulsion vanes in the annular nozzles to reduce momentum losses; unusual planforms; aerodynamic lifting surfaces; etc.

Inherent Stability—With the increasing operating heights, it is highly desirable to maintain the inherent stability of the GEM, especially in the small and medium sizes. This feature is important to wide use of the GEM in military and commercial areas. In conjunction with inherent stability, it is desirable to have positive control including braking and side force control. In general, it appears that the price for stability, control, and trim are paid in horse-power.

continued on next page

The GEM will be at its best where it has no real competition

Jet Blast Effects—The jet velocities of present and future GEM's will be in the range of 100 to 200 fps. These velocities are in the range of those of a ducted fan VTO and 3 to 5 times greater than the helicopter downwash velocity. These velocities produce sand and snow storms, and water spray. They also blow grass and other foreign matter into air inlets as well as the surrounding atmosphere. Water spray can be deflected to a great extent. Ice formed from water spray or melted snow can collect on the hull or at air inlets. However, there are practical solutions to the icing problems.

Grade Climbing — at Present, climbing a 7 per cent grade is considered good performance, but some future applications will demand a grade climb ability of 30 to 60 per cent. To hold on a 60 per cent grade, the thrust required is equal to approximately 50 per cent of the weight.

High Speed Effects—The conventional jet may be a poor cushion sealer in high-speed flight. Other systems are being investigated. One of these, proposed by Hiller, consists of creating a diffusing inlet between the GEM and the ground, thereby producing a stagnation pressure wall. In any case, large variations in the pressure seal will produce base pressure shifts which create trim problems.

Social — The GEM introduces social problems that have yet to be resolved. The FAA does not recognize it as an aircraft. Local ordinances and automotive highway regulations are inimical to GEM's. At present, their least hostile domain is off the highway. GEM-boat types probably fit into present social customs most easily.

Gem Future—The GEM is here to stay; its rate of growth will mostly depend on military requirements. Development costs to produce the ultimate ideas in GEM's are beyond what one would expect a commercial firm to underwrite. Nevertheless, the current art is sufficiently advanced to permit construction of useful vehicles in smaller sizes.

GROUND EFFECT MACHINES
(Nominal Data)

Make	Type	Base	Gross Wt (lb)	Length (ft)	Hov. Ht. (ft)	BHP Total	Weight Empty	Base Area (ft^2)	Comments
A. M. F.	Prototype	AJ	585	—	0.062	9	390	58.9	3 Separate Units
Bell Helicopter	Scooter	PC	340	7.1	0.208	12	160	26.3	Bristle Exit
Bertelsen	Prototype	AJ	585	8.4	0.5	72	410	49.6	Rectangular Planform
Curtiss-Wright	Prototype	PC	1750	16.0	0.25	85	1050	161.0	—
Curtiss-Wright	2500	AJ	2500	21.0	0.5-1.0	360	1260	151.0	Production Version V Max > 50 mph
Curtiss-Wright	Bee	AJ	1115	12.0	0.33	100	555	—	Production Version V Max 53 mph
Fletcher	Prototype	—	—	—	0.3-0.5	72	243	—	—
Gyrodyne	Prototype	AJ	650	—	—	70	480	38.2	Navy Program
NRA	Gem-1	AJ	1200	14.6	0.75	66	800	104.0	Army-Marines
Princeton	X-2	—	300	—	0.42	5	120	38.4	Scooter
Princeton	X-3	AJ	1000	20.0	1.0	49	850	314.0	Circular Planform
Saunders-Roe	Hovercraft SR-N-1	AJ	8500	30.0	1.0	450	—	565.0	Crossed Channel
Spacetronics	Prototype	PC	1000	18.0	0.33	—	800	127.0	—
Weiland	Prototype	AJ	14,000	33.0	0.67	700+	—	990.0	Flown 50 mph on part-power

The GEM will be at its best where it has no real competition. That is, it must create a domain of its own. Actually, most transportation systems have followed this pattern. It is unlikely that the GEM will replace the motorcar. It is preferable to think of a GEM somewhat as a supplement to the automobile.

Small GEM's will have their uses, but the large ones are of particular interest, since they represent a new system of public transportation. The large GEM would serve as an auto ferry—in a wider sense of the word. It can also be used to remove traffic from highways by flying along roughly prepared ground or along rivers. Such ferries would be capable of carrying over 1000 cars at a time.

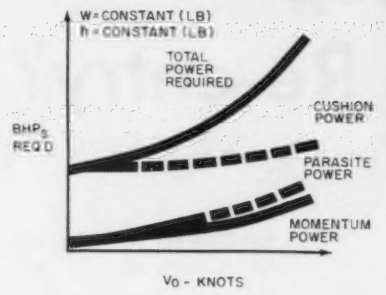
Large transatlantic GEM's are considered to be about 10 years away. Both car and passenger ferries are possible, but the car ferry makes more interesting speculation. The ultimate GEM would cross the ocean in less than a day. One ferry GEM could carry 1000 or more parcel delivery trucks. On arrival, these could be dispatched to various parts of the U. K. or the Continent to deliver their goods.

A passenger-car ferry, equivalent to the parcel delivery GEM, would have the following characteristics:

Gross Weight	7000 tons
Length	800 ft
Width	500 ft
Total Power	400,000 hp
Design Operating Height	15 ft

Normal operating height would depend on ocean conditions, but a height of 15 ft would clear 90 per cent of the ocean waves. Over a year's operation, the average operating height would be less than this. A fare of $100 for car and load would put a European trip within the means of the average family. This implies a nominal daily revenue of $100,000 per GEM. The operation would create a mass transportation system unprecedented in history.

Fig. 4 GEM POWER DISTRIBUTION IN FORWARD FLIGHT



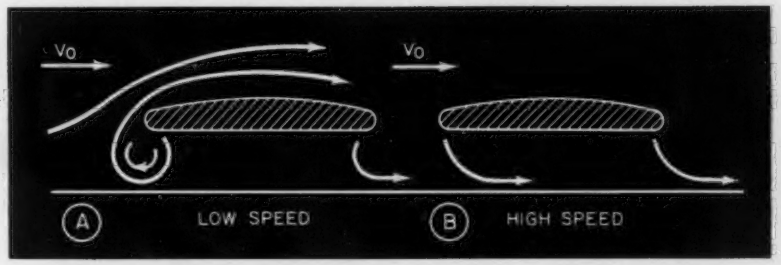


Fig. 5 AIR-FLOW PATTERN around a moving GEM varies with velocity. (A) Below a critical speed, jet flow circulates up and over vehicle; (B) Above critical speed, jet is swept away and produces the "jet-flap" condition.

Unlike any other (earthbound) method of transporation, the GEM is a challenge to each one of them. Therefore, it is vulnerable to comparative judgment from all directions. This includes comparisons with boats, ships, passenger cars, trucks, helicopters, airplanes, hydrofoil craft, and even rigid airships. These comparisons are not necessarily valid, because the GEM will seek out a domain of its own. It can be argued that the GEM must compete economically with other transportation methods. This is true to a limited extent. If, for example, hovering capability is desired, how can a conventional airplane compete economically with a helicopter? Each has its own domain, and each does best where it has little or no competition. The economic aspect is fundamentally important in commercial operations, but this aspect is limited to the fact that the operation exists in the first place. The operation exists at all, because it satisfies something in humans that ultimately becomes a necessity.

A GEM system can be devised to provide substantially cheap mass transportation across the Atlantic, such that the trip takes one day. The individual can take his car, family, and luggage at a low cost. This means a typical family with two to three weeks' vacation can travel to Europe with only two days in transit. No existing transportation system has the capability of conducting this operation, which fits so well within the social-economic habits of the American family.

The GEM will seek out a new market, which the airplane and surface vessel failed to create. With such modest beginnings, the GEM can become in a relatively few years the instrument for creating a social revolution.

✦

GEM BACKGROUND

Earliest ideas on air-cushion vehicles date back to the late 19th century. During the 1930's, there was a revival of interest pioneered by D. K. Warner and Dr. A. Kucher in the U. S., and T. Kaario in Finland. Serious work on the GEM began in the 1950's. In 1953, C. Cockerell in Britain started his work leading to the 1959 Channel crossing of the "Hovercraft" machine.

The first NASA report published on GEM's was the work of VonGlahn; the results appeared in TN-3982 released in April, 1957. This report played a large part in widening official interest in GEM's. To a great extent, this interest was due to the efforts of Dr. V. Berinati of the Navy Department. Navy-sponsored GEM research has been carried out by the Bureau of Ships and DTMB. Principal investigators include Lt. L. Cathers, B. Silverstein and A. Hirsch in the Office of Naval Research; official interest is represented by Maj. J. Wosser, USMC, and Lcdr. A. VanTuyl, Jr., USN. In the Army, the Transportation Corps has shown the greatest interest in GEM's. Directing the research activities is Lt. Col. G. McConnell in the Surface Research Division of TRECOM. W. Sickles is the chief engineer. OTAC (Ordnance Tank and Automotive Command) and the Maritime Administration have also sponsored work in the GEM field. In October, 1959, the first Government-Industry Symposium was held at Princeton University.

Private organizations which have pioneered GEM activities are Spacetronics, founded by Bollum and Crowley, National Research Associates, headed by William Alper, and the Aerophysics Co. with Dr. G. Boehler. In the U. S. A., there are few aircraft firms that are not looking into GEMS, and at least keeping up with the state of the art. As a rough estimate there are 200-300 individuals in the U. S. formally investigating the ground effect machine.

In Europe, in addition to Cockerell, Kaario and Carl Weiland of Switzerland are active in the GEM field. The Russians have shown some interest in GEM's. Except for some published artists' conceptions and references to activities, little is known of their work. It is known that Ref 7, has been translated by the Russians.

Funding

In the past, financial support of the GEM industry has been at a very low level. A rough estimate of the money to be spent in 1960 amounts to about one million dollars. A guess as to the amount to be expended in 1961 is two to three million dollars. These figures include military programs and private ventures.

1. *Crewe, P. R., and Egginton, W. J., The Hovercraft—A New Concept in Maritime Transport. Paper presented to the Royal Institution of Naval Architects. (London)—19 November* 1959.

2. *Liberatore, E. K., A Parameter for Comparing Ground Effect Vehicles. Aero Space Engineering—October,* 1959.

3. *Boehler, G., Remarks on the Ground Effect Machine. Proceedings—5th Annual Western Forum—American Helicopter Society—September,* 1958.

4. *Chaplin, H., and Stephenson, B., Preliminary Study of the Hovering Performance of Annular Jet Vehicles in Proximity to the Ground. David Taylor Model Basin—Aero Report* 947—*August,* 1958.

5. *Chaplin, H., A Preliminary Design Technique for Annular Jet Ground Effect Machines. David Taylor Model Basin—Aero Report* 966—*September,* 1959.

6. *Boehler, G., and Spindler, R., Aerodynamic Theory of the Annular Jet. Aerophysics Company—Report AR* 581-*R —December,* 1958.

7. *Boehler, G., Aerodynamic Theory of the Annular Jet. Institute of Aeronautical Sciences—Preprint No.* 59-77—1959.

8. *Boehler, G., Basic Principles of Ground Cushion Devices. SAE Annual Meeting, Detroit, January,* 1960. *Preprint No.* 133*A.*

9. *Matthews, G., and J. Wosser, Ground Proximity—A Critical Review. Inst. of Aero Sci. Paper* 59-121—*June,* 1959.

10. *Chaplin, H., Ground Cushion Research at the David Taylor Model Basin. Paper presented to Institute of Aerophysics, University of Toronto—October,* 1959.

A REPRINT

of this article can be obtained by writing on company letterhead to The Editor, AIRCRAFT & MISSILES Chestnut & 56th Sts., Phila. 39, Pa.

Can VTOL Rotor Concept Be Used For Re-entry?

Folding blade-system shows possibilities for re-entry braking and landing maneuvers; Likened to autorotating helicopter descent

by Chester R. Haig, Jr.
Research Dept.
Bell Helicopter Corp.

Use of a rotor for re-entry braking and landing, offers potential advantages for spacecraft. Among these are the possibility of steeper re-entry angles than could be tolerated by a fixed-drag-area body without excessive accelerations, and long supersonic glide ranges.

As a portion of company-sponsored research in advanced helicopter concepts, Bell Helicopter Corp. has studied the use of rotors for such purposes.

Regimes of flight which a spacecraft must negotiate to return to Earth are: re-entry flight, lower-atmosphere flight, and ground contact.

During "re-entry flight," dissipation of kinetic energy by aerodynamic drag would avoid using large amounts of retro-rocket fuel. "Lower-atmosphere flight" is the regime between re-entry and landing, i.e., from point where heating is no longer a significant problem, to the start of actual landing maneuver. In this regime, landing point would be selected and vehicle maneuvered into an approach pattern. In the "ground contact" regime, the vehicle would be slowed to the point where ground contact could be made safely.

Rotor - Landing Concept — A possible rotor landing system for the Mercury capsule does not involve fundamental modification to the capsule; a rotor system is merely substituted for the parachute canister. The rotor blade cover would support the nose drive safety rocket installation.

During a return-to-Earth maneuver, rotor would be deployed past the aerodynamic heating regime, and would first be used as a drag-producing device in the trailing axial-flow attitude.

After the rotor, in axial-flow position, has slowed the vehicle down to helicopter speeds, cyclic controls would be applied and a helicopter - type power - off glide would be accomplished. Helicopter-type flared landing would be preferred for a piloted vehicle since the pilot could keep the horizon in view while watching the landing spot; kinetic energy required for this type is somewhat less than in a vertical landing, and pilot errors result primarily in horizontal residual velocity rather than in vertical residual velocity.

Vertical-type landing would most likely be used in an automatic system designed to guide vehicle down a vertical or slant radio beam from a low-powered radio transmitter near the landing point.

Rotor Opening—Rotor opening and rpm buildup in axial attitude can be done entirely by aerodynamic forces, provided rotor is pre-opened mechanically, enough to project blades into airstream, and blade pitch is set to some angle other than flat pitch. A slight initial rotation would cause centrifugal forces to spread blades to a position giving larger acceleration forces, and rpm would build up rapidly thereafter.

Rotor opening, rpm and drag characteristics can theoretically be controlled by collective-pitch adjustments. Through collective pitch setting, pitch-flap coupling, and selection of pre-opening angle, it is possible to adjust the opening rate.

Rotor Drag—In axial attitude rotor drag depends on flight speed, rpm, and blade pitch. At low speeds, maximum drag is obtained by setting the pitch near flat, and allowing rpm to build up until tip speed is near the maximum possible; this is 5 to 20 times the flight speed, depending on flight Mach number and airfoil. During high-speed flight blade pitch is set at an angle which will stabilize rpm at a structurally-tolerable level. In general, there are two blade-pitch set-

ROTOR LANDING-SYSTEM FOR ONE-MAN CAPSULE

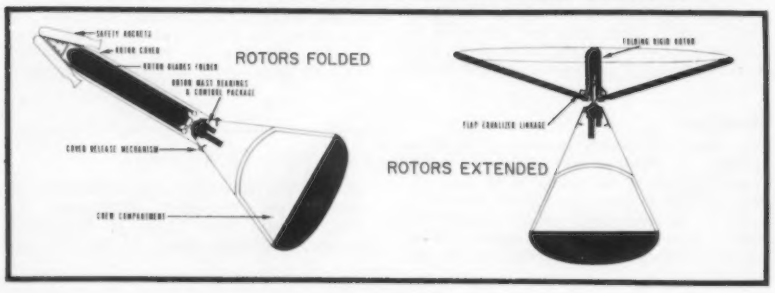


Fig. 1. VARIATION OF AIRSPEED WITH ALTITUDE (subsonic opening case)

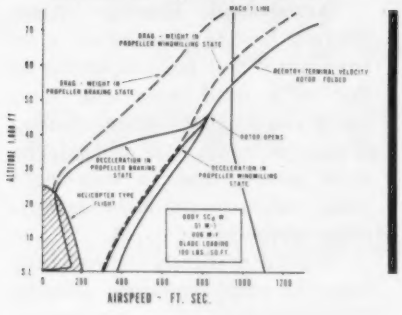
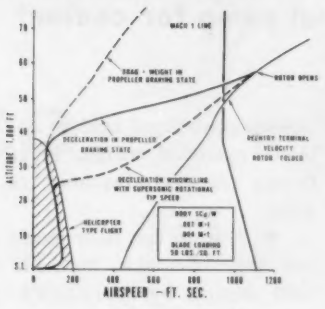

MACH 1 LINE
DRAG - WEIGHT IN PROPELLER WINDMILLING STATE
DRAG - WEIGHT IN PROPELLER BRAKING STATE
DECENTRY TERMINAL VELOCITY ROTOR FOLDED
ROTOR OPENS
DECELERATION IN PROPELLER BRAKING STATE
DECELERATION IN PROPELLER WINDMILLING STATE
HELICOPTER TYPE FLIGHT
ALTITUDE - 1,000 FT
AIRSPEED - FT. SEC.

Fig. 2. VARIATION OF AIRSPEED WITH ALTITUDE (supersonic opening case)


MACH 1 LINE
DRAG - WEIGHT IN PROPELLER BRAKING STATE
ROTOR OPENS
DECELERATION IN PROPELLER BRAKING STATE
DECENTRY TERMINAL VELOCITY ROTOR FOLDED
DECELERATION WINDMILLING WITH SUPERSONIC ROTATIONAL TIP SPEED
HELICOPTER TYPE FLIGHT
ALTITUDE - 1,000 FT
AIRSPEED - FT. SEC.

tings at which rpm will stabilize at below maximum rpm: (1) at a very high negative pitch with which the mean blade chord lines are approximately parallel with the helix generated by blades; (2) with nearly flat pitch with which the rotor acts as a system of centrifugally-spread flat-plate drag elements. We have distinguished these two operating states by calling them the "propeller windmilling state" and "propeller braking state," respectively. Operation with blades near flat pitch, i.e., in the "braking" state is required to provide large amounts of drag with restricted rpm.

Plots of airspeed versus altitude were calculated for two sample vehicles as a measure of the adequacy of a landing rotor to slow vehicles to helicopter speeds. These plots are presented in Figures 1 and 2.

In the case of Fig. 1, it is necessary to operate rotor in the "braking" state rather than the "windmilling" state, to slow to helicopter speeds before ground impact; rotor would be opened at about 45,000 ft, at speeds of 800 ft/sec to reach helicopter flight speeds near the ceiling for helicopter operation.

In the case of Fig. 2, it would be desirable to operate rotor in the "braking" state, to reach the ceiling of helicopter flight for maximum glide range; opening the rotor at about 56,000 ft at 1150 ft/sec will slow the vehicle to helicopter speeds, near ceiling for helicopter flight.

Supersonic & Transonic Flight —Operation of a rotor in clean supersonic flight, in the axial symmetric attitude, does not appear to offer basic theoretical difficulties. If any difficulties are encountered, because of compressibility, they will probably be caused by rotor operating in an irregular body wake at transonic speeds at which the body is buffeting. This may lead to rotor and body vibrations.

Analysis of a rotor operating in the fully-stalled propeller-braking state indicates that a rotor, in the trailing position, will contribute to the directional stability of vehicle; and that some maneuvering is possible if the usual helicopter cyclic-pitch controls are provided.

Portions of this analysis have been confirmed qualitatively by tests, using a model landing-rotor system. Step-by-step integration of rotor torque and rpm-decay during a vertical landing shows that rotor kinetic energy, available in slowing the rotor to minimum hovering rpm, should be about four times the vehicle's kinetic energy before collective pull-up.

Optimum technique in a vertical landing is to allow rpm build up till blade tips reach their drag divergence Mach number (for maximum ratio of rotor kinetic energy to falling kinetic energy) and perform deceleration at about 2.5 g, reducing thrust towards end of maneuver as rpm drops.

Lift-drag ratios obtainable depend primarily upon ratio of vehicle parasite drag area (in glide attitude) to rotor disk loading. Attitude at which a helicopter glide can be started depends on blade loading, i.e., vehicle weight divided by total rotor-blade area.

Lift-drag ratio for a vehicle will be about 3 to 1, helicopter glide ceiling about 25,000 ft, and resultant glide radius about 12 nautical miles.

Rotor System Weight—A rotor for a landing system can be somewhat lighter than a standard helicopter rotor in spite of the provision for a folding hinge. The rotor does not have to be designed to withstand engine torque. It is reasonable to restrict maximum speed in glide (which determines the amplitude of periodic blade bending loads) to a lower speed than would be acceptable for a general-purpose helicopter.

In selection of disk loading, for a landing-rotor system two opposing trends are at work. A high disk-loading results in a small diameter, reduced structual weight, a faster rate of descent, and increased blade weight needed for rotor kinetic energy. Lightest rotor system would be one with a disk loading low enough so that designing for structural strength only results in a heavy enough rotor for the required kinetic energy. Preliminary studies show that in a 1000 to 10,000-lb vehicle a disk loading of about 2 lb/ft^2 results in the lightest rotor for a vertical landing, and about 3 if a flared landing is used. Higher disk-loadings would require weighted blades, greater centrifugal force, and greater grip weight. Lower disk loadings result in a slightly heavier basic rotor, with surplus kinetic energy, because of lower rate-of-descent.

Advantages — A rotor landing system, though heavier than a parachute system, can perform three functions not performed by a parachute landing system.

- Glide to a precision spot landing with considerable glide range for final correction of navigation.
- Arrest vertical impact velocity at touchdown which is important on ground landing.
- Arrest wind drift at touch-

Blades would be cooled on "hottest" re-entry; Centrifugal force, natural pump for coolant

down, also important in ground landings.

For ocean landings a parachute system and enough deadrise to the vehicle's bottom to cushion the water impact would seem adequate. For hard ground landings, within continental areas, the parachute system would need augmenting by an impact-energy absorbing system. This may consist of inflatable landing bags, extra parachutes, collapsible structure, or a heavy-duty hydraulic landing gear. Such equipment eats away the weight advantage of parachute system. Further, a continental landing would be convenient and economical.

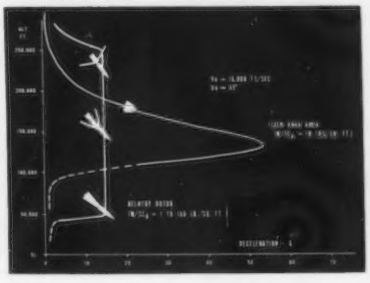
A rotor landing system requires either a pilot or an electronic system, to guide the vehicle and/or time the application of controls. In the absence of some control or guidance, the rotor can perform a simple parachute function; its advantages include less opening shock under high dynamic pressure conditions, and quicker folding after use than a parachute.

Hypersonic Flight — Conventional helicopter rotors use rotational tip speeds of 3 to 4 times the maximum flight-speed of the vehicle, to avoid loss of lift capability on retreating blade. Operation of rotor in this manner, in supersonic flight, would lead to structurally-intolerable tip speeds. With a heavy-blade re-entry rotor adequate centrifugal force can be developed for holding blades extended with moderate tip speeds, say 200 to 500 ft/sec.

Preliminary theoretical analysis of rotors operating in hypersonic flight has given the following indications:

- Lift, drag, and unbalancing moments are not significantly different from those of stationary airfoils held in the same position relative to the wind, i.e., rotation provides a centrifugal field to hold the blades extended, without greatly affecting the aerodynamics of the array.
- A rotor can be trimmed in a low angle-of-attack, high lift drag ratio attitude by applying two-per-rev cyclic feathering. A comparison between the lift drag ratio potential of fixed-wing and rotating-wing aircraft shows that above about Mach 4, rotor provides essentially same lift-drag ratio potential as a fixed wing. Of course, the rotating-wing aircraft would have to be equally well streamlined to realize equal lift-drag ratios, and this may not be easy to do.
- The rotor is stable in the trailing axial symmetric attitude, and rpm can be readily controlled by collective pitch adjustments. Application of one-per-rev cyclic feathering will enable rotor to be trimmed in a slightly-skewed attitude to develop low lift drag ratios.
- When used primarily as a drag-producing device, a rotor tends to even-out variations in drag due to variations in atmosphere density. This feature may help reduce peak decelerations during a steep re-entry. A fixed-drag area re-entry body would subject the occupants to a peak deceleration of about 54 g, in the re-entry assumed in Fig. 3. The rotor, if mounted to a low-drag body and assuming appropriate rpm regulation, would adjust to density variations and subject the occupants to only 15 g deceleration.

Fig. 3. DECELERATION vs ALTITUDE IN STEEP RE-ENTRY



Aerodynamic Heating — Aerodynamic heating of blades of a re-entry rotor will be comparable to that of a fixed wing with same chord and similar airfoil. Heating of a rotor blade will probably be more intense than in wide-chord wings, which results in lower Reynolds numbers.

If rotor is slightly skewed away from the axial symmetric attitude, to produce some lift in combination with drag, heating rate is reduced because of the higher flight attitudes during deceleration. This also reduces heat concentrations at airfoil edges since they alternate rapidly. Peak edge-heating rates are reduced about one-half by such alternation. Blades will probably have to be cooled to withstand severe steep re-entries. Centrifugal force provides a simple means for pumping coolant liquids and vapors through the blades.

Landing—Power required to turn a rotor in low-speed flight is primarily induced power, i.e., power for deflecting or accelerating large volume flows of air. Blade profile drag accounts for only about 25 per cent of the total energy dissipation. Hence, rotor performance during a slow glide, and during the landing flare and hold-off, would benefit from a small amount of extra weight. This would increase rotor kinetic energy, and offset compromises in blade airfoil, to improve re-entry characteristics.

If we assume that a re-entry rotor will be larger, heavier, and have more blade area than a rotor designed for landing only, we can also assume that it will have a better ratio of kinetic energy available for landing.

✦

This article is based on a paper presented at the IAS 28th Annual Meeting.

A REPRINT

of this article can be obtained by writing on company letterhead to The Editor, AIRCRAFT & MISSILES Chestnut & 56th Sts., Phila. 39, Pa.

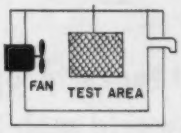
here's 4 ways

CARDOX® CO_2

can help you achieve
versatile... fast... low cost

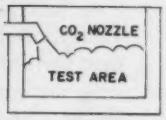
BELOW 0° F. ENVIRONMENTAL TESTING

1 dry ice chamber



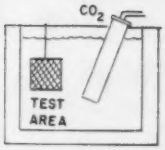
Simple, easy, inexpensive. A fan blowing over a wire basket full of crushed dry ice will reduce chamber temperatures from 0 to —70°F. A quick, low cost method for making occasional or isolated cold tests.

2 direct discharge of liquid CO_2



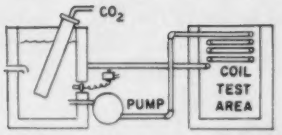
Easiest, most efficient method for consistent, cold testing in production operations. Bulk liquid carbon dioxide is discharged directly into the test chamber. You get controlled test conditions from 0 to —100°F. in 60 seconds or less. Best of all, one CO_2 storage tank can serve a battery of test chambers.

3 immersion tank method



For low cost production-line cold testing. Crushed dry ice or bulk liquid CO_2 is injected into an acetone, methanol or trichlorethylene base solution. Items to be tested are immersed in the slurry which has a temperature of minus 109°F. An ideal method of making cold "shock" tests.

4 indirect cooling method

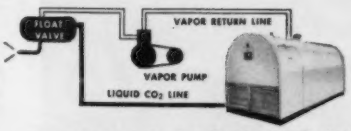


Bulk liquid CO_2 is discharged directly into refrigerant line or surge tank containing acetone, methanol or trichlorethylene type solution. Refrigerant is then pumped thru test chamber to reduce temperature by means of coil-type heat exchanger. Major advantage—no CO_2 atmosphere in test chamber . . . an important factor where this condition is not desirable.

This exclusive feature can save you up to 15%
CARDOX® PATENTED RE-CYCLING SYSTEM keeps Liquid CO_2 COLDER . . . minimizes vapor loss

Low pressure liquid Carbon Dioxide storage tanks are located some distance from the point of use. Heat in the piping may vaporize a part of the liquid CO_2 so that vapor as well as liquid CO_2 arrives at the nozzle. This is undesirable for several reasons.

1. The vapor has reduced refrigerating effect and results in a loss of CO_2.
2. The vapor causes intermittent discharge; discharge rate and control is affected.
3. Starting may be delayed as large amounts of vapor must be discharged before pipe cools sufficiently to eliminate creation of vapor.
4. Vapor discharge can interfere with temperature control accuracy.



The exclusive Cardox Re-Cycling System eliminates these disadvantages.

Float valve just prior to the nozzle separates vapor from the liquid CO_2. A vapor pump connected to a return line pumps the vapor back to the storage tanks.

The new Cardox Re-Cycling System means greater efficiency, control and economy for users of bulk liquid CO_2 systems.

Circle 21 on Inquiry Card

CARDOX systems can be engineered to provide temperature ranges from 0 to —150°
For complete detailed information, or technical assistance in setting up CO_2 testing chambers, write today: Dept. 1627

CARDOX

840 N. Michigan Avenue,
Chicago 11, Illinois

CHEMETRON

A Plan to Increase Helicopter Range Sixfold

"Floating-wing fuel tanks" proposed to give helicopter world mobility

by Charles B. Fay, Research Engineer
Vertol Aircraft Corp.

The normal range of present helicopters is less than 400 mi (n). Even with extra fuel tanks, which require moderate structural change of the helicopter, the range is less than 1100 mi. For the military to take full advantage of the helicopter's versatility, the aircraft should be able to fly to any point in the world in a combat-ready condition. This means it should span the longest leg in the ocean-ferry route—2100 mi. The ferry capability should be achieved with minimum structural modification and weight penalty.

A scheme called "the floating fuel-wing" may achieve this objective. Army Transportation Research Command is funding a study of this plan by the Vertol Aircraft Corp.

In the floating-wing concept, the wing contains and supports the fuel for extended ferry missions. The helicopter provides the propulsion to overcome the wing drag.

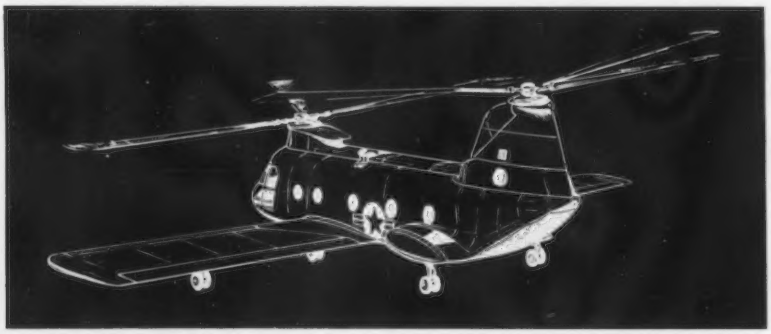
Hinged Attachment—The helicopter is, in essence, towing the wing through the air. A short wing-stub is attached to the helicopter through two main spars. On the outboard end of the stub a hinge, consisting of two bolts mounted in journal bearings, attaches to the main wing-panel. The wing contains fuel in cells between the two main spars. Thus hinged, the outer wing and fuel load float on their own aerodynamic lift. Basic advantage over a fixed wing system is that vertical loads imposed on the wing are not transferred to the fuselage. Hence, structural beef-up of the fuselage is not required and the stability and controllability characteristics of the helicopter are not adversely affected.

When the wing-helicopter combination is on the ground the wing is supported by its own landing gear. To get the wing-helicopter airborne, a running take-off is made. The initial cruising attitude of the wing-helicopter combination is slightly nose-down. As fuel is consumed, the helicopter tends to become less nose-down, due to the reduced drag of the wing. At the end of the ferry mission, the attitude is approximately that of the helicopter alone. Obviously, the trim attitude depends to some extent on the trailing edge flap and wing positions.

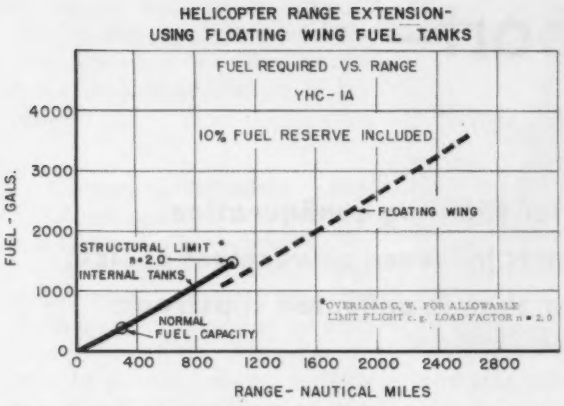
Angle of Attack—As the fuel weight changes, the lift must also change if the wing is to remain in equilibrium. This is accomplished by changing the angle of attack of the wing through a skewed hinge. As the wing becomes lighter, the lift of the wing causes it to flap up about the hinge. Because the hinge is on an angle relative to the chordline, the angle of attack decreases as the wing flaps up. Hence, as the wing weight decreases, the equilibrium attitude of the wing changes.

The skewed hinge allows the wing to seek an angle of attack independent of the fuselage angle of attack. This is essential, since the helicopter's attitude is not necessarily a function of flight speed. If the wing angle were fixed relative to the fuselage, as is the fixed wing system, trimming the system throughout the speed range would become quite difficult, if not impossible.

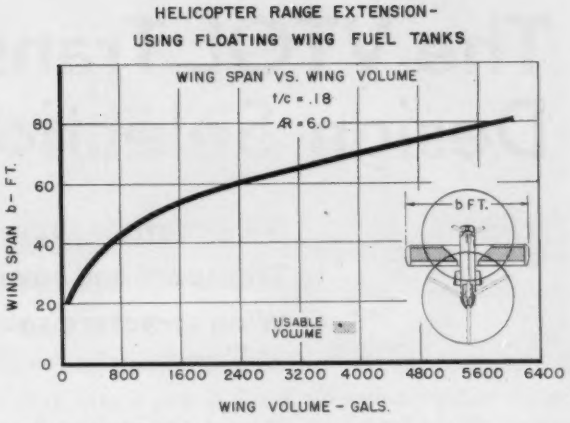
To prevent extreme flapping attitudes in the wing, a flapping attitude trim device is used. Thus, a full span trailing-edge flap is provided to change the attitude of the wing at the pilot's discretion. By raising the flap, the lift decreases. Hence, the equilibrium flapping position of the wing is lowered. The trailing-edge flap may also be used as a high lift device during the running take-off of the system.



STUDY VEHICLE for floating fuel-wing-tank is Vertol built YHC-1A. But conversion kit goal is for all operational helicopters. YHC-1A has normal range of 280 mi, with 1025 mi ferry range.



RANGE EXTENSION to 2500 mi is possible for Army YHC-1A with floating fuel-wing-tank.



WING VOLUME available for fuel is shown as a function of wing span.

Locating the Wing—The optimum location of the floating wing along the fuselage would seem to be at the helicopter's center of gravity. At this location, the wing forces would not impose moments on the aircraft. However, in the steady state condition, the wing lift equals the wing weight and the resultant vertical wing force on the helicopter is zero. Only during the transient state of wing response to gusts, etc., is there a vertical force acting on the helicopter due to the wing. A detailed analog computer study showed that when the wing was located forward of the center of gravity, the system became more stable than the basic helicopter. Hence, the wing should actually be placed ahead of the center of gravity of the helicopter.

For a given amount of fuel, the distribution of fuel between the helicopter and wing, influences the range of the system considerably. Since the average lift-drag ratio of the wing is higher than that of present operational helicopters, the wing can carry the fuel more efficiently than the helicopter. Therefore, the maximum miles per pound of fuel at a given cruise speed is achieved by allowing the wing to carry the greatest percentage of the fuel load.

Operating Techniques — The take-off wing loading varies between 20 and 30 lb/ft^2. The landing weight of the wing is approximately one-tenth that at take-off. Consequently, the wing loading at landing is 2 to 3 lb/ft^2. This structural weight per square foot is only half that of the conventional fixed wing. The light weight indicates the structural advantage of the hinge, which allows the wing to support only its internal fuel load.

The speed for best range of the system differs little from the speed for best range of the helicopter itself.

Cruising altitude for the fuel wing-helicopter system varies as fuel is consumed during the ferry mission. Initially the cruise altitude is low, due to the high power requirements. Because of the favorable specific fuel consumption variation of the turbine engine with altitude, there is a decided fuel advantage in climbing to higher altitude as the system burns fuel and becomes lighter. In studies of turbine helicopters using the floating fuel-wing system, it was found that the maximum miles per pound of fuel was obtained by climbing to 10,000 ft as fuel was consumed and then continuing the ferry mission at that altitude.

As the fuel in the main tank of the helicopter is exhausted, the pilot or crew member can refill the tank by drawing fuel from the wings. A schedule of the order in which the wing tanks are used should be made so that the center of gravity of the wings is near to or coincident with the center of lift. This would minimize loads transferred into the helicopter through the wing stub, which in turn would allow minimum structural weight and modification.

In landing, the pilot flies the helicopter onto the ground. Just as the landing gear makes contact, the majority of the helicopter weight is supported by the rotors and the wing is still self-supporting. The wing is then lowered onto its landing gear by raising the trailing edge flap. Braking force is supplied by a horizontal component of the rotor thrust. Under normal landing conditions, when the wing is lightly loaded, the landing speed is approximately 30 knots.

Wind tunnel tests, sponsored by the U. S. Transportation Research Command, are now being conducted to further substantiate the feasibility of the floating fuel-wing range extension system. These tests, using a powered helicopter model, will determine the stability characteristics of the helicopter with the floating fuel wing and the effect on rotor induced power due to the presence of the wing. A method of jettisoning the fuel wing is also being investigated to allow autorotating descent.

✦

A REPRINT
of this article can be obtained by writing on company letterhead to The Editor, AIRCRAFT & MISSILES Chestnut & 56th Sts., Phila, 39, Pa.

The VTOL Transport—Design Selection

Hiller details reasons for tilt-wing configuration; Transport and hover costs influence powerplant choice; Wing structure sounder than in deflected slipstream

by Philip Geddes

J. B. Nichols, manager of advanced planning at Hiller, says of the X-18, "Our aim in choosing the tilt-wing 'propelloplane' was to attain the design which promised the broadest area of uses, and therefore the greatest probability of a large market." His analysis follows.

The primary purpose of most aircraft is transportation. Transport efficiency is generally more important than hovering efficiency. Fig. 1 compares the cost in forward flight between propelloplanes and helicopters. These costs are based on military factors and are not absolute for civil operation. However, the relative costs are pertinent. The propelloplane has lower operating costs than the helicopter for all radii of action above 50 mi. The operating cost of a tilt-wing propelloplane in an STOL mission is also shown in Fig. 1. If the propelloplane can be allowed to make a conventional airplane type takeoff, it can be overloaded (above permissable VTOL configuration) to provide much higher payloads. Operating costs are shown to be competitive for hovering durations of only two or three min. The choice of design for a particular mission is obviously influenced by hovering requirements.

Fig. 2 shows the relationship of forward flight efficiency to hover efficiency for various VTOL's.

In Fig. 3, power loading is shown as a function of diskloading. The curve shows the rapid decrease in the number of pounds that can be lifted per installed horsepower as the diskloading increases. This decrease of power loading with increasing diskloading has a direct effect on hovering fuel consumption. (See Fig. 4.)

Now, combine power loading and fuel consumption factors, add equipment weight. From this we arrive at a combined lifting system plus hovering fuel weight as a function of the hovering duration in any particular mission. We can see from Fig. 5 that the propelloplane is superior to the helicopter for hovering durations less than ten min, and is competitive for hovering durations up to perhaps half an

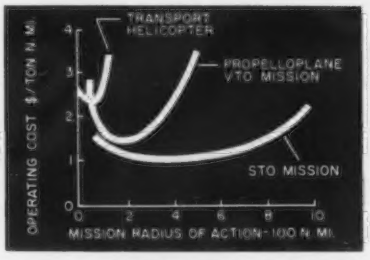


Fig. 1. OPERATING COST vs mission radius of "propelloplane", with 4-ton payload helicopter.

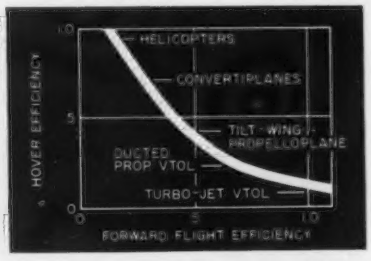


Fig. 2. HOVER AND FORWARD flight efficiency of various VTOL aircraft.

Fig. 3. POWER LOADING as a function of disk loading in a hover state of flight. Payload horsepower drops as disk load rises.

Fig. 4. RATIO OF FUEL consumption in hover state. (Compared with fuel consumption for disk loading = 4).

hour. Turbojet type vertical take-off vehicles are directly reduced. This versatility of tilt-wing propelloplane operation offers one of the major advantages inherent in the design.

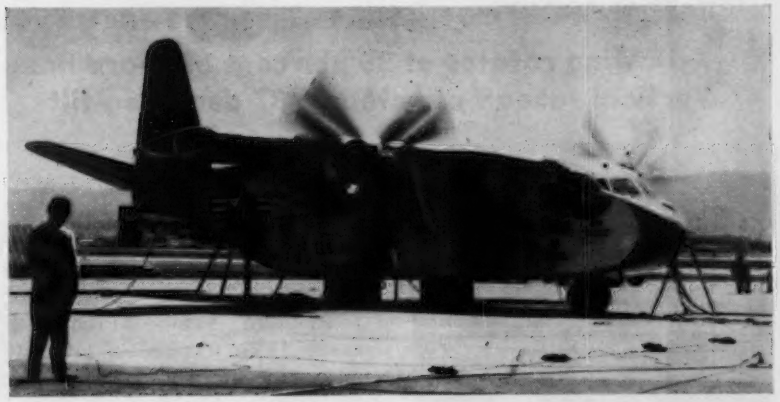
Common Disadvantage — Any VTOL operation has one disadvantage that cannot be overlooked. The helicopter, despite relatively low down wash velocity, raises the problem of ground erosion and dust. This problem is bound to get worse with the propelloplane but obviously not to the same degree as in a high velocity turbojet exhaust. A combination of high velocity and high temperature in the downwash restricts turbojet operation to specially prepared take-off and landing areas. This restriction defeats one of the primary advantages of VTOL aircraft.

Why Tilt-Wing—After Hiller settled on a turboprop powered VTOL aircraft another basic problem had to be resolved—tilt-wing or deflected slip-stream?

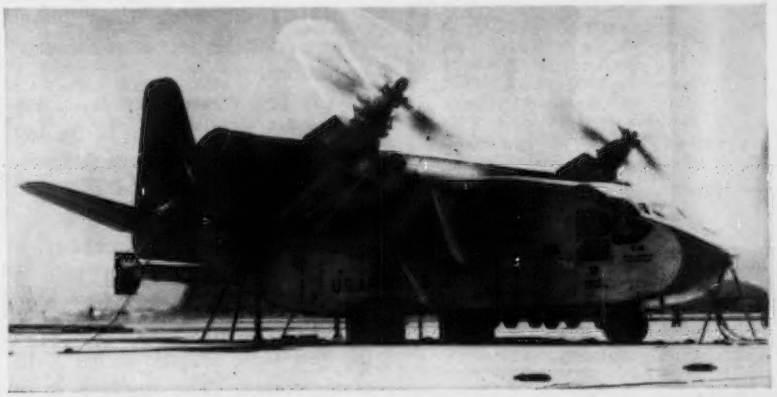
In a deflected slip-stream design the wing remains stationary and a series of large flaps deflect the slip stream downward. One of the major problems in a deflected slip stream type, in comparison with the tilt-wing, is the high pitch-down moment which must be overcome by high downward tail loads (see Fig. 6). These tail loads also mean that additional lift force is required from the lifting system. This double loss is not apparent in a tilt-wing configuration.

Structurally, the large flaps in the deflected slip-stream configuration subtract from the integrity of the wing. The flaps have high loads on them and transfer these loads to a wing whose main structure has been considerably reduced by the need for flaps in the first place. In the tilt-wing, the wing can be designed as a continuous structure (see Fig. 7). No flaps are required and structural integrity can be assured with minimum weight.

continued on next page



NORMAL POSITION of wing is seen in this photo sequence taken during tie-down tests. Angle of incidence is 4.5 deg. Wing is mechanically locked in this position.



PARTIAL ROTATION of wing on hinge point at 35 per cent of chord line is illustrated. Wing is tilted by 2 independently actuated, double acting hydraulic cylinders.

FULL 90 DEGREE rotation can be effected. Wing can be hydraulically locked in any chosen intermediate position. Vertical takeoff setting is 87 deg. Full conversion at 15,000 is planned late March.

X-18 wing rotates at 35 per cent of chord line; Vertical takeoff effected at 87 deg wing-tilt

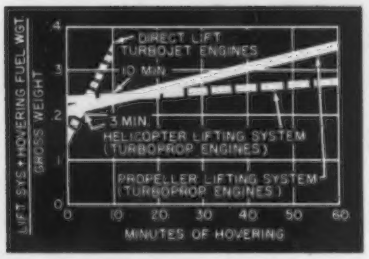


Fig. 5. FUEL WEIGHT RATIOS and large VTOL transport aircraft lifting system.

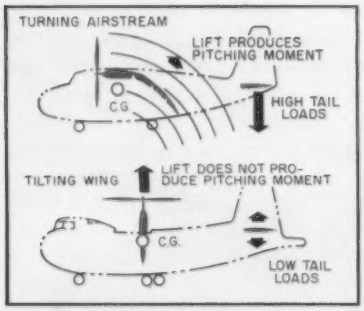


Fig. 6. LIFT EFFICIENCY of slipstream in tilt-wing and flap-deflected configurations.

General Specifications For Hiller X-18

Wing area basic wing	528 sq ft
Horizontal Tail Area	193 sq ft
Vertical Tail Area	121 sq ft
Length Overall	63 ft
Height Overall	24.6 ft
Span basic wing	48 ft
Aspect Ratio (basic wing)	4.3
Design Gross Weight	33,000 lb
Empty Weight (with seats and test instruments)	26,500 lb
Av Rate Climb to 8,000 ft (maxpwr)	6,000 ft/min
Max Fwd Speed (structural limits only)	250 mph
Dive out from hover to fwd flt, pwr off	2,800 ft

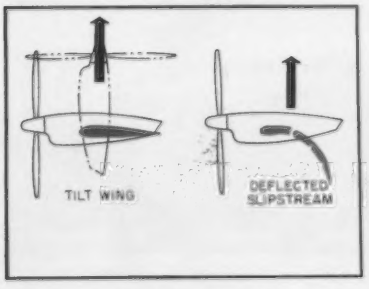


Fig. 7. STRUCTURAL COMPARISON of tilt-wing and flap-deflected slipstream airfoils.

The obvious choice to Hiller was the tilt-wing. And, after four years of study, the X-18 VTOL transport made its first flight on November 24, 1959.

Research Vehicle—From the outset, Hiller decided a tilt-wing test bed must achieve certain basic objectives:

(1) Test data must be applicable to a wide range of aircraft sizes.

(2) The test vehicle must have capacity to carry all necessary flight-test instrumentation on every flight to avoid repeat testing.

(3) Test vehicle must be as close as possible to an "envisioned" operational aircraft.

(4) Test vehicle must be initially suitable for all phases of the test program. Duration must be adequate. Crew protection high. It became obvious that a transport size test airplane would be necessary.

Fuselage—In keeping with a low cost approach, the Chase YC-122 fuselage, empennage and landing gear were adapted to the X-18 configuration. The fuselage is of truss-type tubular construction covered with aluminum alloy sheet over light metal stringers and formers. Redesign of the center fuselage section was necessary to accommodate the wing-tilt system.

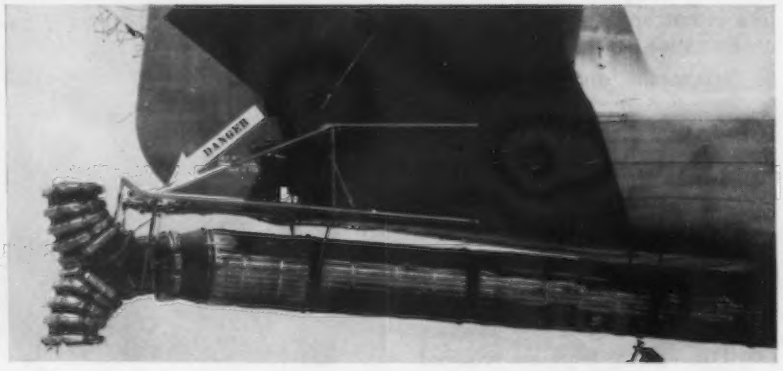
Layout of the cockpit down to the controls is surprisingly similar to a conventional transport. Two upward ejection seats are provided. Some 1200 pounds of flight instrumentation plus a fuel load of approximately 6000 lb are carried in the fuselage.

Power Units — Lifting power comes from two Allison YT40-A-14 turbo-propeller engines driving dual 16-ft diam Curtiss turbolectric propellers.

Wing—The wing consists of a single panel of constant chord and airfoil section (NACA 23015). There are two main spars located at 15 and 35 per cent chord. They extend from root to tip. An auxiliary spar at 75 per cent chord extends over the rear portions of the wing panel. Four hydraulically moved ailerons form the trailing edge sections of the wing. These ailerons become the yaw control surfaces when the wing is tilted. There are no flaps. Provision was made in the wing design for installing fixed leading edge slats, although it is not now contemplated that they will be fitted. Structural provision has also been made for extending the wing span to 60 ft by adding constant chord and section tip panels each six feet long. The wing tip extensions raise the aspect ratio for improved range and load capabilities in STOL tests.

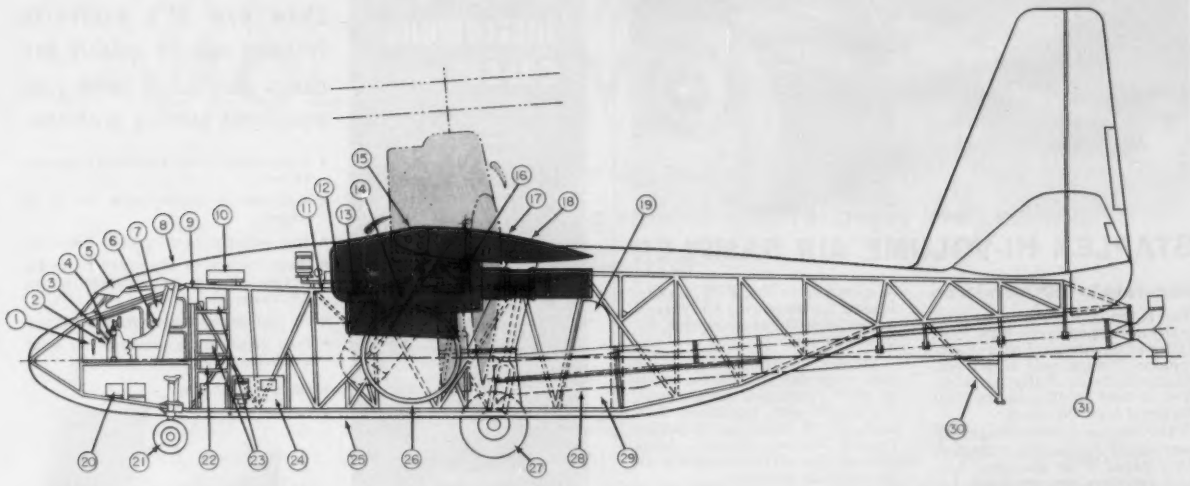
Hydraulic Control System—The X-18 has three completely independent hydraulic systems.

- A utility system for main



PITCH CONTROL DIVERTER supplements conventional elevator. Control vane inside "Y" exit diverts exhaust from fuselage-housed J-34 either up or down.

DESIGN DETAILS OF THE HILLER X-18



1. Rudder and Brake
2. Center Control Pedestal
3. Instrument Panel Instal.
4. Control Column
5. Panel Instal. Overhead
6. Ejection Seats
7. Door — Pilots Comp.
8. Hinged Canopy
9. Auxiliary Distribution Panel
10. Prop Synchronizer
11. Wing Junction Boxes
12. Fuel Control Amplifiers & Relay Boxes
13. Main Distribution Panel
14. Wing-Tilt Cylinder
15. Master Wing Diagram
16. Control Integrater
17. Wing Closure Fairing
18. Pitch Control Engine Air Inlet
19. Fuselage Access. Door Aft.
20. Battery
21. Landing Gear — Nose
22. Radio
23. Flight Test Instrumentation
24. Hyd. Instal. Flight Control
25. Fuselage Access Door
26. Fuel Cell Support
27. Landing Gear—Main
28. Pitch Control Engine Instal.
29. Pitch Control Engine Cowling
30. Guard Instal. Jet Diverted
31. Pitch Control Engine Tail Pipe Instal.

landing gear brakes and nose wheel steering.

• Dual systems for flight control and wing tilting. The flight control systems are closed center type, pressurized to 3,000 psig by two variable volume engine driven pumps, one per wing engine. If one flight control system fails, the alternate system is capable of operating the flight controls and tilting the wing.

Flight Control Systems—For forward flight, conventional aileron, rudder, and elevator surfaces and control systems are provided. The two latter are controlled by a simple cable system—the ailerons being hydraulically actuated. In the cockpit, the pilot sees a conventional yoke/spectacle combination and rudder pedals. The only additional flight control is a lever mounted on the center pedestal that controls wing tilt. This lever controls speed of actuation as well as position.

Pitch Control Diverter — An alternate pitch control system replaces the conventional elevator, while the wing is tilted vertically. Jet blast from the fuselage-housed J-34 is diverted up or down from the exhaust projecting below the tail. A control vane in the blast diverts the exhaust stream up or down as required. Vane position is controlled by a push/pull rod and lever system connected to the conventional elevator segment.

Trim Control — Aerodynamic trim tabs are used on the rudder and elevators. Rudder trim is electrically operated, elevator trim is mechanical. Spring trim systems are provided for roll, yaw, and pitch and are effective at all wing tilt angles.

Major Achievement—It is in the flight control system that one of the main developments in design has taken place. In forward flight the propelloplane is controlled like any other aircraft. The ailerons control roll, the rudder yaw, and the elevator pitch. In transition flight from forward flight to hover, or vice-versa, the pilot operates his controls in the same way as in forward movement and gets the same responses in movement from the X-18. Position corrections from the cockpit are translated to the control surfaces by a mixing box. This mixing control action is accomplished by a strictly mechanical system with no electrical or electronic help.

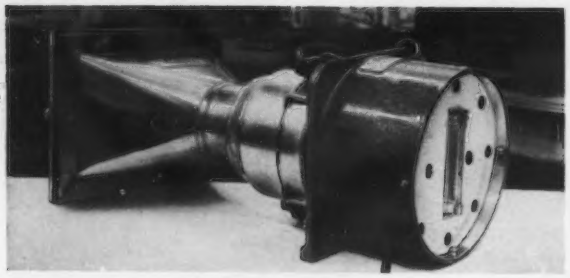
In vertical take-off, pitch movement is accomplished by diverted jet thrust at the special tailpipe, roll by differential thrust of the engine, and yaw by moving the ailerons in the slipstream from the propellers.

In intermediate wing positions, aileron and propulsion thrust forces are mixed to give effective roll control. Intermediate wing position yaw control is provided by the rudder and aileron-thrust mixing.

✦

A REPRINT
of this article can be obtained by writing on company letterhead to The Editor, AIRCRAFT & MISSILES Chestnut & 56th Sts., Phila. 39, Pa.

EASIER, FASTER WAY TO SAMPLE AIR



STAPLEX HI-VOLUME AIR SAMPLER

Accurate to 1/100th micron

This is the same air sampler originally developed by the New York Office of the Atomic Energy Commission. Weighs only 10 pounds. Ruggedly built. Fully portable. Yet, it does in 10 minutes what formerly took 36 hours.

The Staplex samples huge volumes of air by passing it through filter paper 4" in diameter. Special adapters are available for 6x9" and 12x12" filters. A turbine-type blower, *designed for continuous operation*, draws in air at speeds up to 70 C.F.M., making it ideal for measuring all types of airborne particulate matter, indoors or out.

Staplex Air Samplers are being used every day to solve the needs of such companies as: Convair, Curtiss-Wright, Lockheed Aircraft, North American Aviation, Pratt & Whitney, Glenn L. Martin and others. Tell us about *your* air sampling problem.

Available in 110V or 220V AC or DC models; 24V DC. $136.50, f.o.b. Brooklyn, New York.

WRITE TODAY FOR NEW BROCHURE

The Staplex Co., Air Sampler Div., 782 Fifth Avenue, Brooklyn 32, N. Y.

Send me complete information on the Staplex Air Sampler.

NAME_____

ADDRESS_____

CITY_____ ZONE_____ STATE_____

Circle 24 on Inquiry Card

---

standard instrument cases
(At Off-The-Shelf Prices)
Learn how TA's new predesigned Instrument Cases can solve your equipment housing problems.
TA "King-Size" Instrument Cases 4 PAGES
TA Standard Instrument Cases 20 PAGES
Send for your FREE copies . . .
TA mfg. corp.

These free design manuals show how TA's exclusive features can be quickly and easily adapted to solve your equipment housing problems.

- Large selection of standard sizes and styles.
- Available in depths from 2½ to 18 inches.
- Fast delivery (prototypes in 4 weeks).
- Wide choice of standard handles, access doors, panels, and other accessories.
- No tooling charges on standards.
- Free engineering drawings for your exclusive design requirements.

STANDARD ALUMINUM CONSTRUCTION

TA *Mfg. Corp.*

4607 Alger Street • Los Angeles 39, Calif.
(or call CH 5-3748)
TWX 9863 Glendale, Calif. • WUX CAT Los Angeles, Calif.

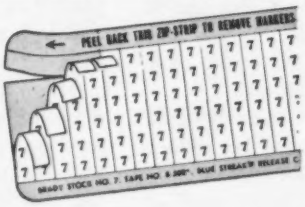
Circle 22 on Inquiry Card

SHORT RUN OR MASS PRODUCTION

These self-sticking products for marking or masking help you get projects "off the ground" faster — whether prototype or production:

WIRE MARKERS

Identify wires, components, harnesses. The only wire marker that can be applied by hand or automatically—at speeds up to 1000 per hour. A marker for every size and type of wire.



SPECIAL MARKERS

Made-to-order markers with any size, color, legends, wordings. 200 self-sticking materials.

QUIK-MASKS

Pre-cut masks for painting, anodizing, vacuum metalizing, solder dipping.

PRINTED CIRCUIT TAPES AND SHAPES

Self-sticking drafting aids for accurate inkless masters.

Write for more information about these and other Brady pressure-sensitive products designed to save prototype or production time.

W. H. BRADY CO., 786 W. GLENDALE AVE., MILWAUKEE 9, WIS.

Manufacturers of Quality Pressure-Sensitive Industrial Tape Products, Self-Bonding Nameplates, Automatic Machines for Dispensing Labels, Nameplates, Masks and Tape • Est. 1914. 98

Circle 23 on Inquiry Card

MIAMI... AN UNLIMITED SOURCE OF SKILLED TECHNICIANS!

There is no shortage of skilled and technical labor in Metropolitan Miami. Skills and semi-skills want to live here and... since workers are happier in their jobs, turnover is generally very low. The Dade County Development Department stands ready to help you with your plant location problems. Our assistance costs you nothing.

Send for complete Economic Study of Metropolitan Miami

A 30-section, economic survey has been prepared to assist you in determining how your operation can profit here. This study will be mailed to you—in strictest confidence—if you write on your letterhead to the address listed below.

WRITE: Richard O. Welsh, Director

DADE COUNTY DEVELOPMENT DEPARTMENT

345 Northeast Second Avenue • Miami • Florida

An agency of the Metropolitan Miami Government

Circle 25 on Inquiry Card

Coleopter— VTOL With Mach 3 Potential

French barrel-wing design lends itself to compounding ramjet and turbojet propulsion; Aircraft is "tail-sitter"

By Ronald A. Cole

The SNECMA Coleoptere when fully developed, is expected to reach speeds in the region of Mach 3. Annular wing configuration of Coleoptere lends itself readily to the requirements of a tail-sitting aircraft.

On the prototype, the diameter-to-chord ratio, is one (1). This gives the basic wing-barrel a lift curve slope of $\frac{1}{2}\pi$ at incompressible speeds. A feature of such wings is that their lift-curve slope is about the same as that for plank wings up to an aspect ratio of two (2). Beyond this figure the slope is progressively less. However when the central pod carrying the jet engine and a jet deflection system are added, the lift-curve slope becomes something well above the $\frac{1}{2}\pi$ value.

Jet deviation was incorporated as a means of control when landing taking off, and transition from one flight regime to another. The method consists of tapping air off the later compressor stages and ducting it down to the exhaust nozzle. There are four main supply pipes and each feeds to a peripheral outlet directed at right angles to the exhaust flow. Each is spaced 90 deg from the other and has means for throttling. Differential action of the outlets causes deviation of the main jet and this provides the control function for vertical flight. Collective action of the outlets provides variable constriction of the main jet and this in turn adjusts thrust.

Direct control of thrust by constriction makes control independent of engine acceleration or run-down time, and allows engine to be run at constant speed.

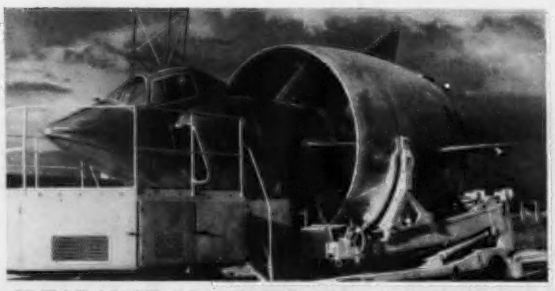
Configuration of the Coleoptere lends itself to compounding turbo-jet and ram-jet propulsion in a tail-sitting aircraft. This development will be seen in the high-speed versions. Burners will be situated between the wing and fuselage to form a very large ram-jet engine.

In the present version, power is supplied by an SNECMA Atar 101 E.V. turbo-jet of 8155-lb static thrust. Dry weight is about 2000 lb, and continuous fuel consumption is about 1.01 lb/lb static thrust/hour. An eight-stage compressor and single-stage turbine are used.

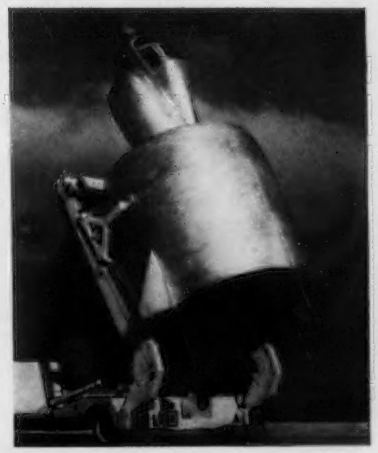
Intakes are canted forward to prevent air starvation, to the turbine, at high angles of attack. Two, retractable, stabilizer-type surfaces on either side of the nose are provided to stop any tendency for the aircraft to roll while hovering.

Annular wing is attached to fuselage by four planes; extensions of these become moveable control surfaces on the outside of the barrel. During forward flight their actions are augmented by deflection of the jet. Small wheels are mounted on the ends of shock absorbers which cantilever out from the barrel trailing edge. Special trailer used for transporting the Coleoptere incorporates an erector for setting up the aircraft in flight attitude.

◆



CLEARANCE DIAMETER of 14.5 ft, across control-surface tips, makes Coleopter conveniently transportable by highway.



TRANSPORTER-ERECTOR combination facilitates placing the aircraft in flight position.

PRECISION PLUS

IN CECO'S SUBCONTRACT MANUFACTURING OF COMPONENTS AND ASSEMBLIES

As a subcontractor, CECO is equipped to handle specifications demanding production tolerances as close as 5 millionths of an inch and finishes to .5 RMS. Representative items manufactured to such specifications are pictured here.

Behind this subcontracting capability are these and other "tools" of CECO's trade:

- machine equipment like Milwaukee-Matics, P&W Magnaspark Automatic Profilers, Sheffield Multi-Form Crush Grinders, Cavitrons, and others . . . much of the equipment tape controlled
- temperature-controlled, contamination-free assembly areas
- spectographic and X-ray inspection equipment
- ultra-sonic cleaning devices
- electronic and computer laboratory facilities along with a wealth of production test equipment and facilities

For more detailed information on CECO facilities and subcontract capabilities, write Department 79 or call W. P. Carpenter, Mgr. Subcontract Sales, ADams 6-0651.

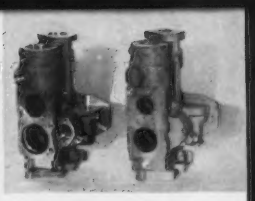
CECO® SYSTEMS CONTROLS

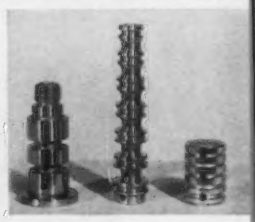
CHANDLER EVANS CORPORATION • WEST HARTFORD 1, CONNECTICUT

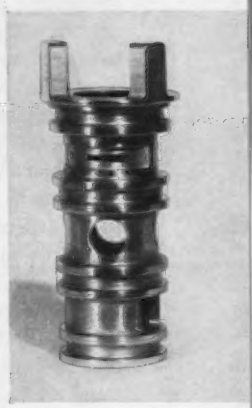
W. B. Gurney
7046 Hollywood Blvd.
Hollywood 28, Calif.
HOllywood 2-1239

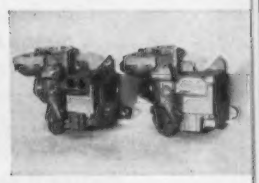
K. L. Moan
305 Spitzer Bldg.
Toledo 4, Ohio
CHerry 8-5791

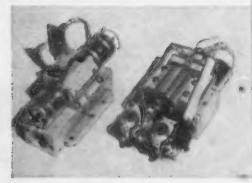
Circle 10 on Inquiry Card











Vibration Nomograph

Reference to two sets of scales enables designers to determine graphically natural frequency of circular plates

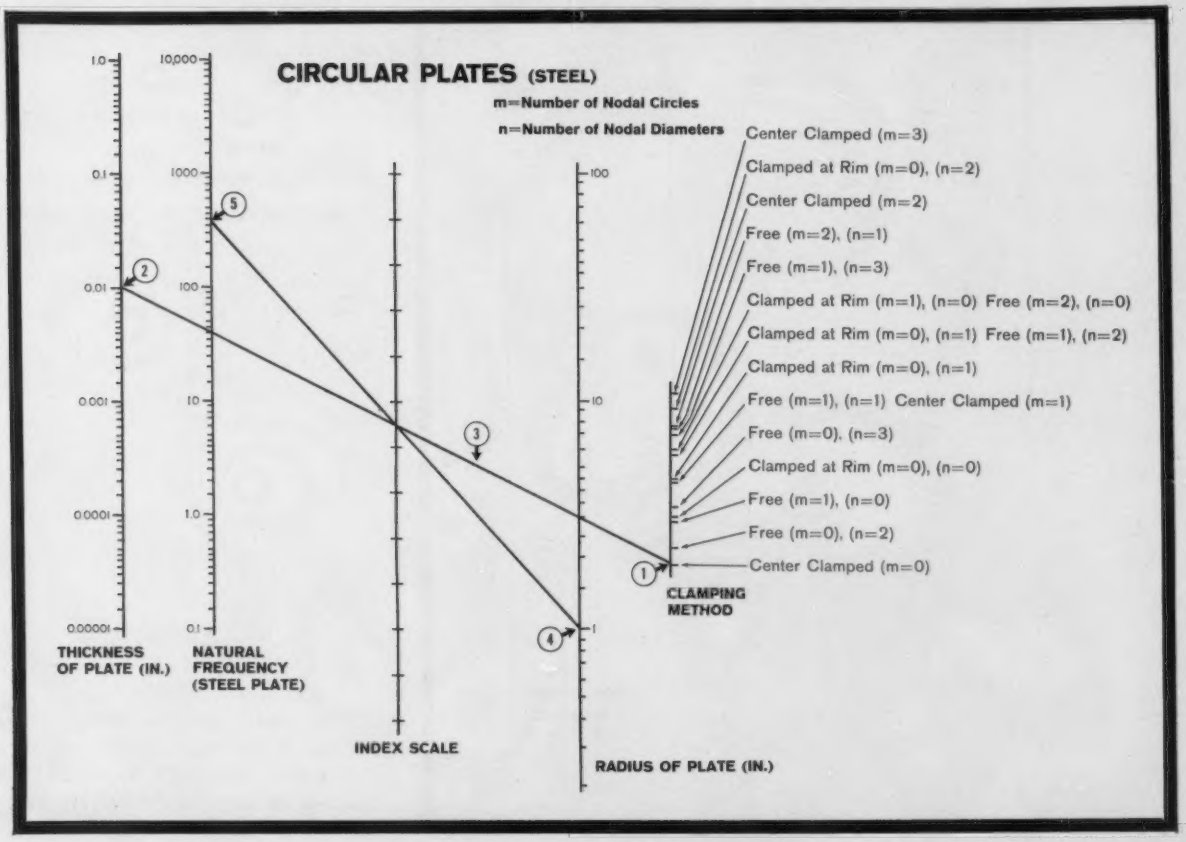
by Dr. Robert L. Peters
Chief Engineer, Neo Co.

Fundamental elements of mechanical design often require the selection or avoidance of natural frequencies; the nomographs presented here simplify finding the natural frequency (f) of circular plates.

Example: A circular plate, made of beryllium, is fixed at the center with a continuous rod. Plate has a radius of one inch, and a thickness of 0.01 inch. Use the following procedure to determine the "f" of this plate.

(1) On "Circular Plate (Steel)" nomograph, on right-hand scale, se-

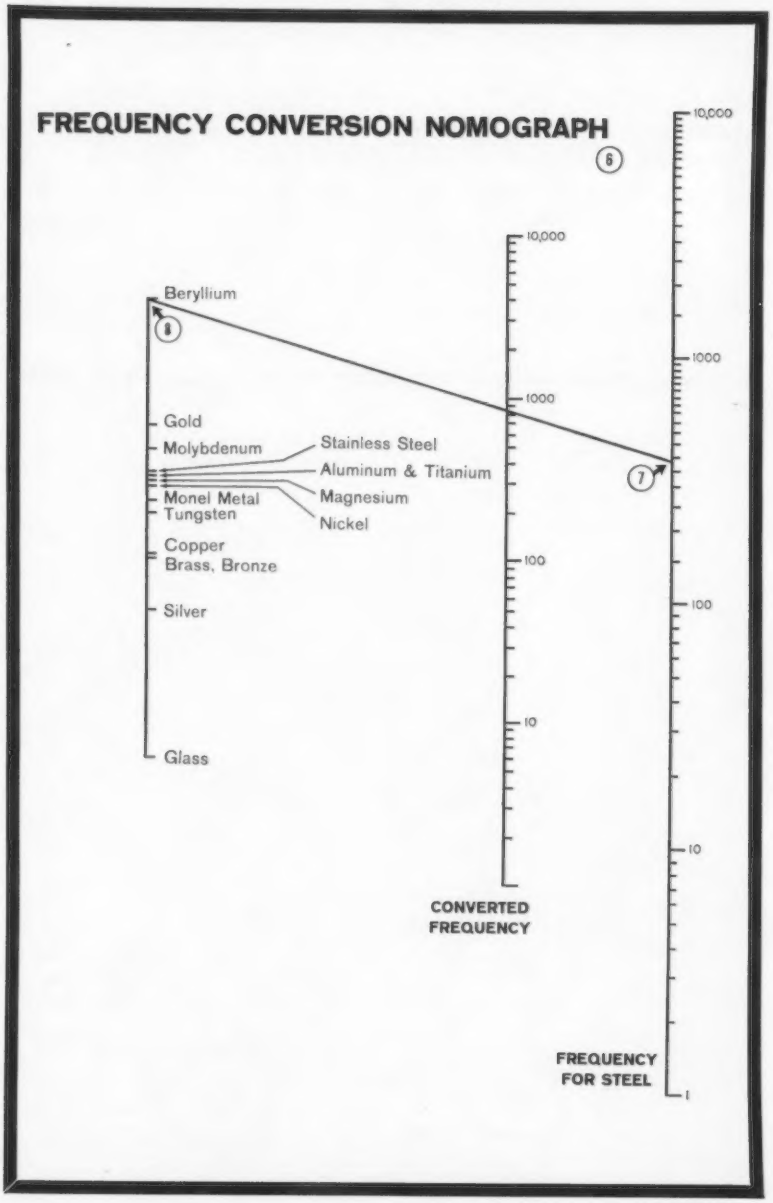
NATURAL FREQUENCY OF STEEL circular plate is established by choosing desired clamping method, thickness of plate and its radius.


CIRCULAR PLATES (STEEL)
m=Number of Nodal Circles
n=Number of Nodal Diameters
Center Clamped (m=3)
Clamped at Rim (m=0), (n=2)
Center Clamped (m=2)
Free (m=2), (n=1)
Free (m=1), (n=3)
Clamped at Rim (m=1), (n=0) Free (m=2), (n=0)
Clamped at Rim (m=0), (n=1) Free (m=1), (n=2)
Clamped at Rim (m=0), (n=1)
Free (m=1), (n=1) Center Clamped (m=1)
Free (m=0), (n=3)
Clamped at Rim (m=0), (n=0)
Free (m=1), (n=0)
Free (m=0), (n=2)
Center Clamped (m=0)
CLAMPING METHOD
THICKNESS OF PLATE (IN.)
NATURAL FREQUENCY (STEEL PLATE)
INDEX SCALE
RADIUS OF PLATE (IN.)

VIBRATION NOMOGRAPH . . . continued

Graphic method gives natural frequency of disks

NATURAL FREQUENCY OF BERYLLIUM circular plate, in this case (or that of other materials listed), is the value established by the intersection of line drawn across "Converted Frequency" scale.



lect clamping method together with nodal circles and nodal diameters desired. For this example, consider center clamping, with m = 0.

(2) On "Thickness of Plate" scale, locate value of 0.01.

(3) With a straight line connect point representing 0.01 value and point representing "center clamping" method. Connecting line indexes a pivot point on index scale.

(4) On "Radius of Plate" scale locate the point representing the one-inch radius. Draw a line to connect this point to the pivot point on "Index Line."

(5) Extend connecting line to intersect the "Natural Frequency" scale. This gives the "f" (cps) for a steel plate.

(6) Now, to find the "f" for beryllium plate, refer to the "Frequency Conversion Nomograph."

(7) Transfer "f" value obtained in (5) to the right-hand scale of conversion nomograph.

(8) Connect this point to the beryllium index on left-hand scale. The point of intersection on middle scale (converted "f") gives the "f" for the desired beryllium plate. The same procedure applies to all the metals listed on the left-hand scale of the "Frequency Conversion Nomograph."

✦

A REPRINT
of this article can be obtained by writing on company letterhead to The Editor, AIRCRAFT & MISSILES Chestnut & 56th Sts., Phila. 39, Pa.

Worth Asking For

Titanium

A 14-page case history study summarizes design considerations which have dictated titanium's current applications in missiles.—*Titanium Metals Corp. of America.*

Circle 55 on postcard for more data

Gyro History

Booklet "The Gyroscope Through The Ages."—*Sperry Gyroscope Co.*

Circle 56 on postcard for more data

Ceramic Elements

Bulletin describes "Michelite" high temperature piezoelectric ceramic elements.—*Universal Dynamics Corp.*

Circle 57 on postcard for more data

Potentiometer Selector

Precision potentiometer selector chart.—*Spectrol Electronics Corp.*

Circle 58 on postcard for more data

Science Careers

Ten-page selected bibliography on science, education and careers for the science and engineering student. — *Scientific Apparatus Makers Assn.*

Circle 59 on postcard for more data

Hand Torches

Revised 36-page catalog on line of gas welding and cutting hand torches, outfits, tips and accessories. — *Air Reduction Sales Co.*

Circle 60 on postcard for more data

Coatings

Bulletin on dichroic coatings. — *Optical Coating Laboratory.*

Circle 61 on postcard for more data

Thermoplastics

Significant physical, electrical, chemical and optical properties of nine thermoplastic materials.—*Cadillac Plastic & Chemical Co.*

Circle 62 on postcard for more data

Electrical Resins

The Catalog on line of "Scotchcast" electrical resins. — *Minnesota Mining and Manufacturing Co.*

Circle 63 on postcard for more data

Electrical Components

Engineering specifications and application descriptions of electrical components for missile and aircraft ground power equipment. — *General Electric Co.*

Circle 64 on postcard for more data

Data Collection

Booklet on "Friden Collectadata" information processing system. — *Friden, Inc.*

Circle 65 on postcard for more data

Batteries

Bulletin Z-101 contains technical data on three new Silvercel batteries for the missile field.—*Yardney Electric Corp.*

Circle 66 on postcard for more data

Servo Systems

New method for teaching servo systems is described—*Servo Corp. of America.*

Circle 67 on postcard for more data

Missile Tracking

Brochure describes ROTI missile-tracking system. — *Electro-Optical Div.*

Circle 68 on postcard for more data

Powerplant Testing

Control and data processing system for testing missile and rocket power plants is described.—*Consolidated Systems Corp.*

Circle 69 on postcard for more data

Wire Glossary

Pocket-sized "Glossary of Wire and Cable Terms."—*Standard Wire and Cable Co.*

Circle 70 on postcard for more data

Theodolites

Brochure describes series of azimuth alignment theodolites used for azimuth accuracy of inertially-guided ballistic missiles — *Electro-Optical Div., Perkin-Elmer Corp.*

Circle 71 on postcard for more data

Aircraft Steels

Booklet on the aircraft steels AM-350 and AM-355.—*Allegheny Ludlum Steel Corp.*

Circle 72 on postcard for more data

Control Valve

Spec sheet on a tank pressurizing control valve.—*Besler Corp.*

Circle 73 on postcard for more data

Laboratory Standards

Precision electrical instruments for laboratory standards described in new color brochure.—*Weston Instruments Div., Daystrom, Inc.*

Circle 74 on postcard for more data

Tubing

Design information catalog for aircraft and missile tubing and duct joint.—*Marman Div., Aeroquip Corp.*

Circle 75 on postcard for more data

Motors and Actuators

New 36-page catalog illustrates facilities and products. — *EEMCO Div., Electronic Specialty Co.*

Circle 76 on postcard for more data

Slide Rule Offered Free

Circular slide rule which simplifies selection of pneumatic pressure regulators is given with new catalog on regulators.—*Stratos Div., Fairchild Engine and Airplane Corp.*

Circle 77 on postcard for more data

Root Problem

Illustrated 20-page treatment of screw thread "roots." — *Standard Pressed Steel Co.*

Circle 78 on postcard for more data

Potentiometers

Bulletin on "Turnquate" line. — *Subminiature Instruments Corp.*

Circle 79 on postcard for more data

Aircraft Supplies

Catalog of aircraft supply items offered by leading firms.—*Aircraft Components, Inc.*

Circle 80 on postcard for more data

Tach Generators

Types of motor Tach generators described.—*Avionic Div., John Oster Manufacturing Co.*

Circle 81 on postcard for more data

Receiving Systems

Brochure describes the firm's capabilities, facilities, and products. — *LEL, Inc.*

Circle 82 on postcard for more data

Seals

Bulletin on high temperature and high pressure seals. — *Skinner Seal Div., Hydrodyne Corp.*

Circle 83 on postcard for more data

Resistance Welding

Wall chart contains data for users of resistance welding electrodes and accessories.—*Ampco Metal Inc.*

Circle 84 on postcard for more data

Plastics

Booklet answers basic questions on types of plastics and how they are produced.—*The Society of the Plastics Industry.*

Circle 85 on postcard for more data

Honeycomb

Technical Service Bulletin 107 reports plate shear strength of welded stainless steel honeycomb, Condition ½ C versus Condition A. — *Hexcel Products, Inc.*

Circle 86 on postcard for more data

Ultrasonic Cleaning

Ultrasonic equipment for cleaning flat and convoluted metal filter element surfaces is described in illustrated folder.—*PALL Corp.*

Circle 87 on postcard for more data

New Materials

New Tungsten Alloy

A new high-temperature alloy is performing successfully at temperatures up to 1750°F in jet engines. It is used for turbine nozzle vanes in the J-57, on 707 and DC-8 airliners. Known as WI-52, the alloy contains 13 per cent tungsten and supplants the X-40 alloy, which has been in use since 1941 with an operating peak of 1600°F. Some other uses might be in hot tools for forming, furnace components and brazing fixtures. — Stanford Research Inst.

Circle 88 on postcard for more data

Vinyl Jet Cover

A vinyl disc solves a critical sealing problem created by the prolonged time between an engine being received and the time it is actually mounted on the DC-8. During this period extensive component assembly work is done. The vinyl barrier is engineered to come in contact with the engine at the inlet guide vane case only. This allows technicians unhampered access to the cowl and nose bullet without disturbing the barrier.—B. F. Goodrich Chemical Co.

Circle 89 on postcard for more data

Dry Film Lubricant

A dry-film lubricant called Hi-T is now available in quantity lots. Its effectiveness has been proven on the hinges of the afterburner-speed brake on Republics F-105. Preliminary data is also available on its use in GE's jet engine program. In this thrust-bearing application it withstood a load of 1400 psi rotating at 720 rpm. Test duration was 3 hr.—General Magnaplate Corp.

Circle 90 on postcard for more data

Electronic Teflon

A new plastic, "Teflon" 100, is expected to find wide markets in the electronics industries. Known as an FEP-fluorocarbon resin, it can be extruded or molded in thermoplastic processing equipment. Electrical insulating, anti-stick, and frictional characteristics are excellent and it will not absorb moisture. Heat resistance is about 100° lower than TFE resins.—E. I. du Pont de Nemours.

Circle 91 on postcard for more data

Copper-Clad Laminate

A new copper-clad, hot-punch, paper-base phenolic laminate is flame-retardant. The material is called either Fireban 321-R or Fireban 321-E, depending on whether copper foil is rolled or electrolytically deposited. It is offered in sheets of approximately 36 x 48 in. with thicknesses from 0.020 to ¼ in. Base stock is translucent and can be cold-punched to 1/16 in. thickness.—Taylor Fibre Co.

Circle 92 on postcard for more data

Rocket-Case Steel

Unimach UCX2 is a cobalt modified AISI 4100 series steel developed for high performance rocket motor cases, and other national defense purposes which require 0.2 per cent yield strengths of 225,000 to 235,000 psi. Its contributions to ease of manufacture through excellent forming characteristics and good weldability help account for its success in critical applications. —Universal-Cyclops Steel Corp.

Circle 93 on postcard for more data

Missile Glass

Glass with improved infrared transmission has been developed for high performance IR-guided missiles, and optical instruments. Detection of relatively low-temperature targets is possible with the new glass. In a thickness of 2 mm, the glass will transmit 77 per cent of the infrared at wavelength of 4.0 microns, and 38 per cent at wavelength of 5.5 microns. At 600°C, there is no transmission loss at 4.0 microns; only 13 per cent loss at 5.5 microns. 7-in. diam domes can be automatically pressed. Larger sizes can be made to order.—Corning Glass Works.

Circle 94 on postcard for more data

Rocket Liner

A molded-rubber liner can be used with solid propellant rocket motors. The synthetic is produced for Minuteman's third stage. It is fabricated in thicknesses ranging from 0.1 to 1.2 in. It "burns out" simultaneously with the expulsion of the solid propellant, reducing the weight and gauge of the casing and leaving the mass ratio at its greatest when the rocket reaches peak altitude.—Goodyear Tire and Rubber Co.

Circle 95 on postcard for more data

Silicone Curing Agent

RTV silicone rubber is more easily prepared with three new paste-type curing agents. By diluting the older liquid curing agent in a paste, a greater quantity is required to effect a cure. As a result, it is much easier to accurately weigh and measure the catalyst.

Addition of color to the paste helps assure complete mixing and dispersion. — Silicone Products Dept., General Electric Co.

Circle 96 on postcard for more data

Ni-Cr Wire Alloy

Chromel-R, a new modified 80-20 nickel-chromium alloy said to possess optimum properties for the manufacture of precision wirewound resistors and potentiometers. It consists of 74 per cent Ni and 20 per cent Cr plus small percentages of alloying elements. Properties include an electrical resistivity of 800-ohms/cmf at 20°C, and a low controlled temperature coefficient of resistance.—Hoskins Mfg. Co.

Circle 97 on postcard for more data

Lo-Shrink Epoxies

Oxiron, a family of epoxy resins, exhibits low shrinkage and low exotherm on cure. These properties, combined with low temperature curability and lower density than conventional epoxies, make the new resins ideally suited to casting and tooling applications.

The resins will wet glass fibers and show good adhesion on cure. Laminates with excellent strength to weight ratio can be prepared under low pressure in relatively short cure cycles.—Food Machinery and Chemical Corp.

Circle 98 on postcard for more data

Epoxy Structures

Intermediate-density (I. D.), structural materials may broaden design concepts for structural engineers. These intermediate-density materials (20 to 40 lb/ft^3) are distinguished from low-density plastics foams. The I. D. structural materials are formulated from several compounds, chief of which would be an appropriate epoxy resin blended with low-density microballoon type fillers. Shear strength of 2000 psi is not uncommon. Below specific gravity of 0.6 they are not pourable.—Furane Plastics, Inc.

Circle 99 on postcard for more data

continues on next page

Name Your Application!

Do It Better With *Thermo Electric* Thermocouple Extension Cables and Wires

You can obtain Thermo Electric thermocouple extension wire and cable in the widest variety of size, insulation, type and calibration, for your application—with prompt delivery of all standard materials.

New on the stock list, is the time and labor saving "Thermo-Cable," from 6 to 56 matched pairs of I.S.A. color-coded thermocouple leads, individually insulated in PVC—collectively wrapped in "Mylar" aluminum-backed tape—with a tight-fitting PVC outer sheath. "Thermo-Cable" is practically impervious to moisture, abrasion, temperature, gasses and chemicals. Saves you the time, cost and effort of pulling individual wires through conduit.

Individual or duplex thermocouple and extension wires are available in all standard calibrations—many in gages from 14 to 40—insulated with Polyvinyl Chloride, cotton lacquer, Nylon, Teflon, Fiberglass, Asbestos or combinations of these materials. Metallic overbraids of stainless steel and other high-temperature materials provide extra mechanical protection and shielding.

"Ceramo", Thermo Electric's metal-sheathed ceramic insulated thermocouple wire is used for extra-high temperature and nuclear applications.

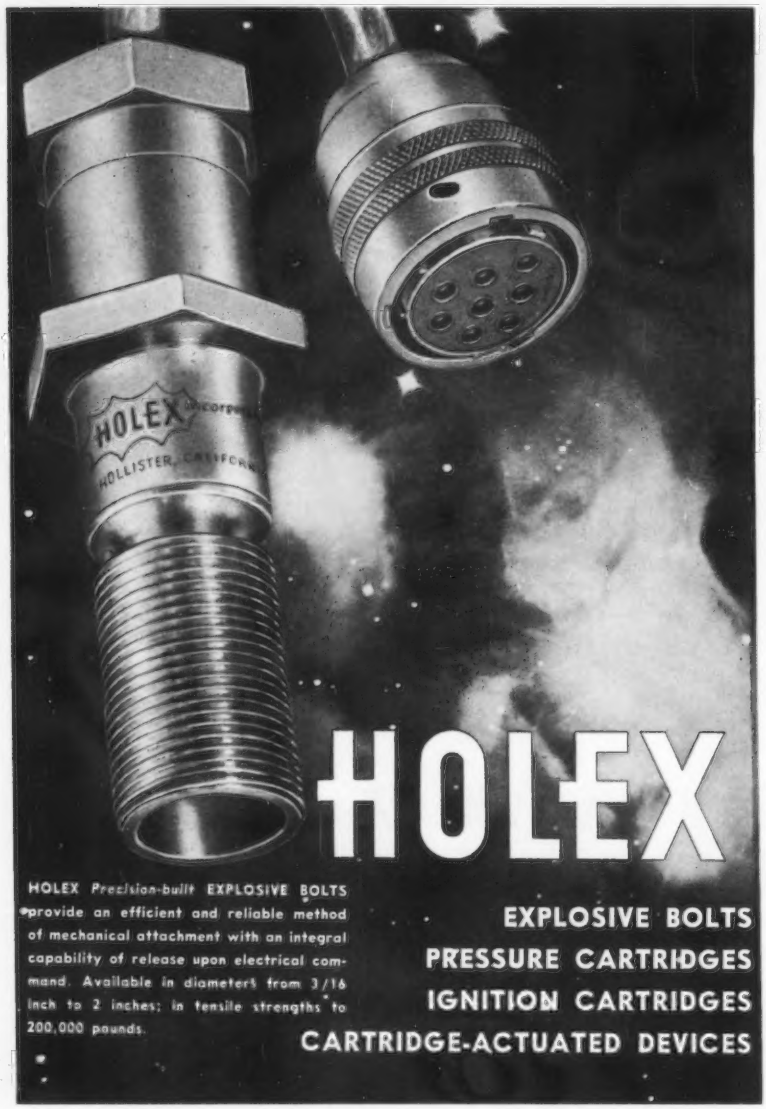
Thermo-Electric also supplies thermocouple wires to meet Mil-Spec requirements.

For information on selecting the right wire for your application,

write today for Bulletin 32-W5-1

Thermo Electric CO., INC.
SADDLE BROOK, NEW JERSEY

In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ont.



HOLEX *Precision-built* EXPLOSIVE BOLTS provide an efficient and reliable method of mechanical attachment with an integral capability of release upon electrical command. Available in diameters from 3/16 inch to 2 inches; in tensile strengths to 200,000 pounds.

Select from thousands of HOLEX precision explosive components the type to meet your ignition, pressurization, mechanical release, safe/arming, valving, and switching requirements. Choose HOLEX for maximum product reliability where minimum weight, positive action, and rugged resistance to environments are of utmost importance.

For Your File
HOLEX TECHNICAL DATA SHEETS
tell about HOLEX ignition cartridges, pressure cartridges, explosive bolts, and cartridge-actuated devices. DEPT. C.

HOLEX incorporated

Design, Development, Test and Manufacture of Precision Explosive Components.

2751 SAN JUAN ROAD, HOLLISTER, CALIFORNIA

New Materials

Vibration Damper

A new noise and vibration damping material can control the resonant response of structures exposed to high-frequency vibration and "white" (wide band) noise. Designated Dyna-damp, it uses a special form of BTR (Broad Temperature Range) elastomer which maintains damping resistance from –65° to 250°F. Dyna-damp laminated panels consist of plies of metal plates with BTR elastomer sandwiched between the plates and bonded to them. Weight of a typical panel is 1.01 lb/ft².—Lord Mfg. Co.

Circle 100 on postcard for more data

New Polyester

Merlon, a plastic to be marketed this spring, is a linear aromatic polyester of carbonic acid. Its chemical stability is comparable to polystyrene, polymethacrylate, and cellulose esters. It is stable against water, dilute mineral and organic acids, and saturated aliphatic hydrocarbons. It is not resistant to alkaline materials. — Mobay Chemical Co.

Circle 101 on postcard for more data

Dual-Coated Wire

Resistance alloy wire with a dual high-temperature insulation of ceramic and Ceron (TFE) is now available. The wire can operate continuously at 250°C, and up to 300°C for short periods. The combination of a ceramic undercoating with an overlay of Ceron imparts better mechanical and electrical properties than a ceramic or a (TFE) coating alone. The rubbery surface has a slick self-lubricating finish.—Kanthal Corp.

Circle 102 on postcard for more data

New Parts and Components

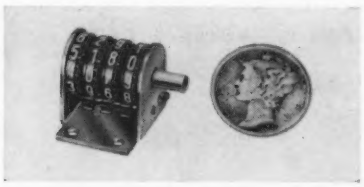
Altimeter

Radioisotope density altimeter measures radioactive back-scatter, proportional to atmospheric density, at high cruise altitudes; it has been developed for use in high-performance missiles and jet aircraft. System consists of four major units: probe, radioactive source, detector and electronic circuits. The probe, a precision-machined, 30-in. long aluminum or melamine tube is mounted usually at a wing tip. Radioactive source is secured on the side of the probe. Atmospheric back-scatter from the source, a beta-emitting radioisotope with long half-life, is detected by a stilbene-impregnated plastic scintillator, then sensed by a photomultiplier tube, amplified and counted on a scaler.—Boeing Airplane Co.

Circle 103 on postcard for more data

Drum Contour

Model 3523 four digit reversible counter has geneva movement pinions and gears molded of impact resistant thermoplastic. Diameter of drums is 0.460 in.; has ⅛ in. high numbers.



It is furnished with a mounting bracket, but the lugs may be clipped off and two screws used in the base for mounting.—Haydon Instrument Co.

Circle 104 on postcard for more data

Magnetic Shield

Compact "Rictometer" device shields out external magnetic fields

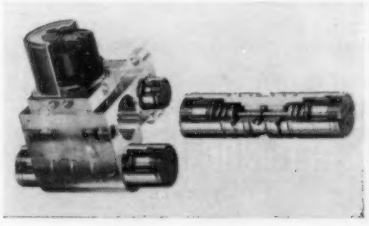
for calibrating aircraft compass transmitters and magneto-meters. More than 99 per cent of the Earth's horizontal magnetic field may thus be eliminated, while creating a known horizontal field adjustable through 360 deg. It can be used in any shop or laboratory location without regard for magnetic disturbances.—General Electric Co.

Circle 105 on postcard for more data

Servo Valve

Derivative pressure feedback electro-hydraulic servo valve features integral damping. It is for use in control systems where servo response is limited by load resonances. The valve functions as a flow-controller statically and has the combined characteristics of a pressure controller and flow controller dynamically.—Hydraulic Research and Manufacturing Co.

Circle 106 on postcard for more data



Control Valves

These automatic control valves were designed to meet the missile launching requirements for Polaris-firing submarines.

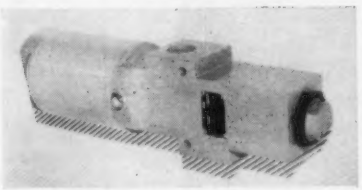
One type is a single-stage pressure regulator that provides air at constant, relatively-low pressure,

from a high pressure storage system; some of this air is used to maintain proper pressure in the launch tubes prior to launching.—Garrett Corp.

Circle 107 on postcard for more data

Flow Regulator

Precision HI-FLO regulator for fluids or gasses is designed to operate in a pressure range 0 to 8000 psi, and is adjustable from 8 psi



to full inlet pressures. It has a response time of less than 50 milleseconds from lock-up to full flow or from full flow to lock-up. Can be regulated with 15 psi differential between supply and regulated pressures.—Solrac Inc.

Circle 108 on postcard for more data

continued on next page

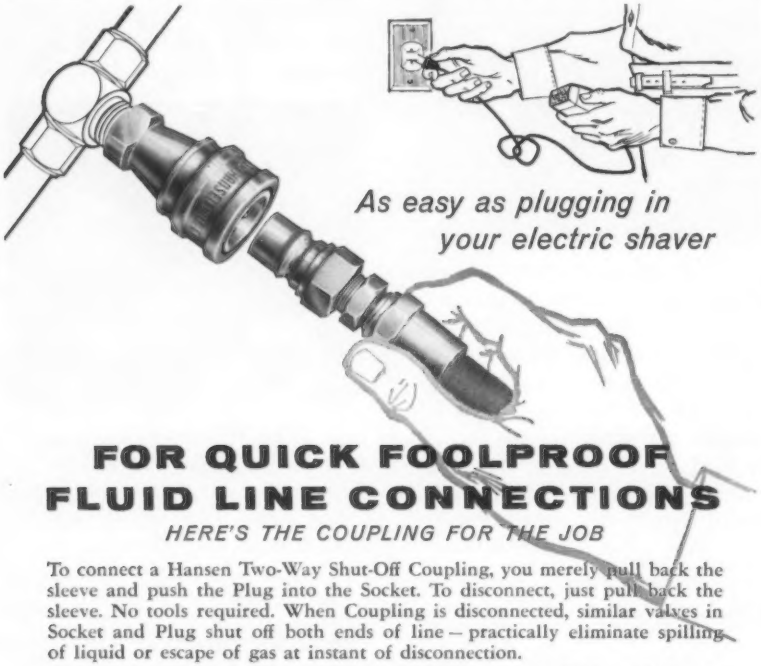
New Parts and Components

Separation Nuts

Separation Nut for missile separation systems is called safer and more efficient than release methods presently used. It finds specific application in multi-stage vehicles, nose cones, capsules, launching pads and sleds, as well as in tanks and jettisonable equipment.

The controlled separation design principle of the Separation Nut is unique when compared to the conventional explosive bolt. The principle combines a highly reliable mechanical separation which is activated by a small explosive charge. —Hi-Shear Rivet Tool Company.

Circle 109 on postcard for more data



FOR QUICK FOOLPROOF FLUID LINE CONNECTIONS

HERE'S THE COUPLING FOR THE JOB

To connect a Hansen Two-Way Shut-Off Coupling, you merely pull back the sleeve and push the Plug into the Socket. To disconnect, just pull back the sleeve. No tools required. When Coupling is disconnected, similar valves in Socket and Plug shut off both ends of line – practically eliminate spilling of liquid or escape of gas at instant of disconnection.

Hansen Series HK Two-Way Shut-Off Couplings are available with female pipe thread connections from ⅛" to 1" inclusive. Available in brass or steel.

WRITE FOR THE HANSEN CATALOG

Here's an always ready reference when you want information on couplings in a hurry.

VISIT OUR BOOTH '60

Booth 2019

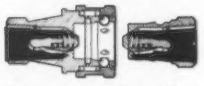
SINCE 1915

HANSEN

SERIES HK®

TWO-WAY SHUT-OFF COUPLING

Instantly shuts off both sides of line . . . prevents loss of liquid, gas, or pressure.



QUICK-CONNECTIVE FLUID LINE COUPLINGS

FOR COMPRESSED AIR • HYDRAULIC FLUIDS • OIL • GREASE
WATER • VACUUM • STEAM • OXYGEN • ACETYLENE
REFRIGERANTS • GASOLINE • COOLANTS • LP-GAS

REPRESENTATIVES IN PRINCIPAL CITIES

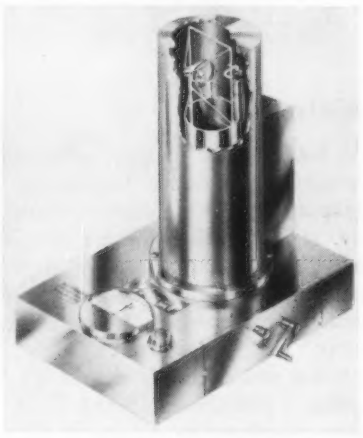
QUICK-CONNECTIVE FLUID LINE COUPLINGS

THE HANSEN MANUFACTURING COMPANY

4031 WEST 150th STREET • CLEVELAND 35, OHIO

Pressure Gage

This non-mercurial pressure gage features a compact and rugged fused-quartz mechanism. Advantages claimed include low hysteresis,



pressure reproducibility with constant accuracy, and a low temperature coefficient. Gages are available in four pressure ranges: 0-1, 0-40, 0-80 and 0-120 in. H.G., repeatable to within one part in 30,000.—Buck Instrument Co.

Circle 110 on postcard for more data

Crash Recorder

A system to enable probers to determine the cause of an air disaster within hours of the actual crash time has been developed. Miniaturized continuous data recording system automatically ejects itself clear of the crashed aircraft. The crash recorder was developed from equipment for inflight data analysis and recording. — Royston Instruments, Ltd.

Circle 111 on postcard for more data

Self-Locking Bolt

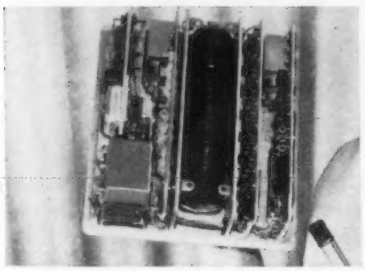
Vibration resistant self-locking bolt meets MIL-F-18240 and MIL-F-5577B specifications for collapsible fuel cell applications. This bolt incorporates a strip of locking material pressed into a milled slot, and is reusable many times without appreciable loss of torque.—Long-Lok Corp.

Circle 112 on postcard for more data

New Electronic Products

Nuclear Gage

Transistorized fuel gage uses atomic energy to give increased accuracy and reliability. Gage automatically accounts for differences in hydro-carbon, or petroleum-based, fuels which affect the accuracy of conventional devices. It consists of gamma radiation sources, such as Cobalt - 60, scintillation detectors



containing a ratemeter and pulse amplifier, a power supply and an indicator.—Atomics International

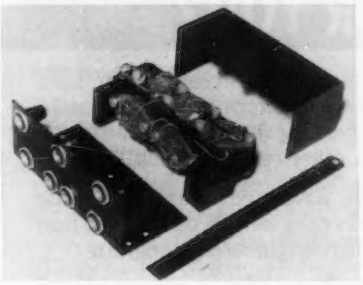
Circle 113 on postcard for more data

"Aspirin" Switch

New Klixon AT1-1 ("aspirin tablet") precision switch establishes a miniaturization record for hermetically sealed switch design. It weighs less than 1/28 oz. Size reduction is

achieved by a unique, snap-acting, "W-blade" element. The envelope dimensions of the AT1-1 are 0.320 in. dia by 0.440 in. length. Hermetic sealing is accomplished by applying the techniques of seam and stitch welding. Welding eliminates solder flux contamination and contributes to miniaturization. — Texas Instrument Corp.

Circle 114 on postcard for more data



Hi-Speed Switch

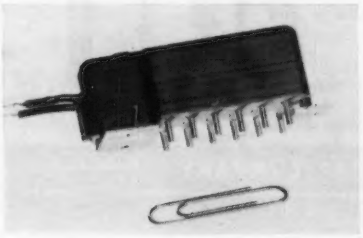
A high-speed sequencing switch regulates electrical pulses so that electro-mechanical locks can be opened at 10 millisecond intervals. Performance is achieved by transistorizing the switch. Switch has the intrinsic ability to wait for a limited time to allow a sticky lock to operate. After this period has passed a special safety device operates to allow the sequencing to continue for the other locks. — Microcell Electronics, London

Circle 115 on postcard for more data

Explosive Switch

Explosively actuated switch can break six circuits simultaneously. Originally designed for a specific missile, the XM-9 switch is now offered for general military or commercial applications. XM-9 measures approximately 2 x 1 x 9/16 in. It weighs only 1½ oz.—Dial Service and Mfg. Co.

Circle 116 on postcard for more data



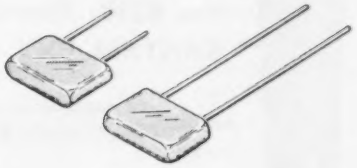
Cooling Modules

"Thermoelectric modules" provide compactness, silent operation with no moving parts, and a controlled cooling rate in electronic units. Modules are designed in a variety of shapes and sizes for simple mounting in any position. Can be physically paralleled to cool a large flat area, or stacked in series like building blocks for increased cooling. Units can maintain a 25°C temperature differential at a load of 17 BTU's per hour.—Westinghouse Electric Corp.

Circle 117 on postcard for more data

Solid-State Limiter

Microlectron solid state current limiter is designed for electronic circuits where ultimate protection is required. The limiter acts 300 to 400 per cent faster than any related device known. It is a one-shot deal



which fires in less than 1 millisecond at 316 per cent rated value, or 1/10 sec at 150 per cent rated value. The limiter is available in ratings from 1/32 amp to 5 amp in 2 configurations.—Microlectron, Inc.

Circle 118 on postcard for more data

Rugged Tape Unit

Miniature tape recorder is designed for reliable operation over wide temperature range under extreme shock and vibration conditions. The recorder is now in use by

continues on next page

WHAT MORE DO YOU WANT GRAPHITE TO DO FOR YOU?

Graphite has been useful in aircraft and missile problem-solving as a component material in rocket motors, in brazing fixtures for airframe construction, and in other refractory applications.

Further and more advanced uses of graphite in space age progress may well be developing now as part of your design engineering program.

As one of the world's largest producers of high quality graphite, we would welcome having our engineers and technicians work with you on these developments.

May we have the pleasure of hearing from you?

PRODUCTS YOU CAN TRUST — GLC — ELECTRODE DIVISION

GREAT LAKES CARBON CORPORATION

18 EAST 48TH STREET, NEW YORK 17, N.Y. OFFICES IN PRINCIPAL CITIES

Circle 29 on Inquiry Card

NOW in 50 WATTS for MINIATURE and SUBMINIATURE PRODUCTION SOLDERING JOBS

the *NEW,* American Beauty BANTAM "X" series

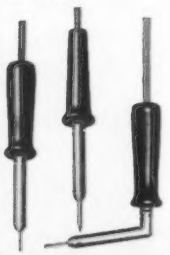
⅛" TIP

Designed with 50 watt input, these fine soldering irons will give greater productivity and do industry's most exacting soldering jobs easier, faster, better. SLOTTED STAINLESS STEEL CASINGS MAKE THE HANDLES REALLY COOL, ending operator complaints. There's no waiting or fumbling with these light, flexible tools — they're always ready. American Beauty soldering irons are known the world over for their dependability, durability and efficiency. Learn more about these fine soldering tools today.

YOU CAN'T BEAT A SOLDERED CONNECTION

WRITE FOR DESCRIPTIVE CATALOG SHEET, FORM NO. 222-CT

Shown below are other shapes and tip-size irons available in the BANTAM "X" series.



204-B

¾₆" TIP

AMERICAN ELECTRICAL HEATER COMPANY

DETROIT 2, MICHIGAN

American Beauty

New Electronic Products

Air Force on space probe projects, and by Navy in testing the Subroc missile.

It is completely self-contained but requires external power. All-metal surface recording heads, and modular construction are featured.

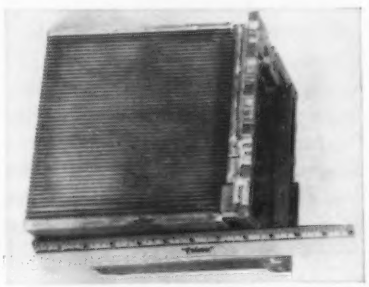
The unit can be driven in either direction and contains an end-of-tape sensor.—Leach Corp.

Circle 119 on postcard for more data

Electronics Cooling

Size reduction of 83 per cent is made possible in a 1KW power amplifier on B-58 by completely immersing the power unit in a fluorochemical coolant. The coolant dissipates approximately 1600 watts of heat within an air-tight case. Avionic heat vaporizes the liquid, carrying heat off in the form of vapor. This cooling technique is about 100 times more efficient than simple air convection for transferring heat generated by hot-spot components.—Minnesota Mining and Mfg. Co.

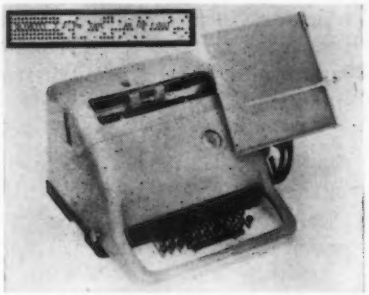
Circle 120 on postcard for more data



New for Production

Teletypewriter Unit

Teletypewriter will produce a printed message on a standard 11/16 in. punched tape fully compatible with electronic readers and integrated data processing systems.



Called the T2PN Printing Reperforator, the unit prepares a conventional, fully-perforated, five-channel tape. At the same time, the machine prints a typewritten message between the feed holes of the perforated tape.—The TELautograph Corp.

Circle 121 on postcard for more data

Transistor Tester

ITVAC (Industro Transistor Value Automatic Computer) can test 750 transistors per hr, classify

them according to programmed specifications, and record the test data. It is believed the fastest and most complete transistor tester available.

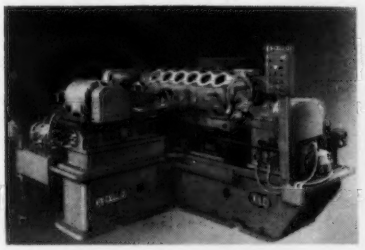
Programming is done by a direct reading dial system. Entire programming operation may be done in 2 to 5 min.

Test results are read and/or recorded on a system which includes a 4-digit, digital voltmeter and a recording system feeding an IBM 526 (or similar) Printing Summary Punch.—Industro Transistor Corp.

Circle 122 on postcard for more data

Boring Machine

Precision boring machine uses standard machine slides and other building block components, including a total of eight precision boring spindles.



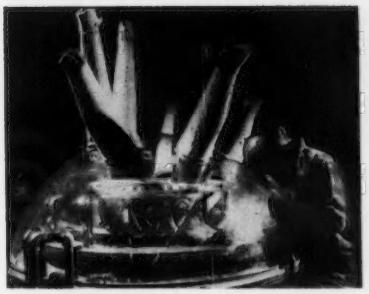
Workpiece, a massive aluminum alloy V-12 engine crankcase, is manually clamped on the fixture table, this being carried on a standard hydraulic slide. Two other standard slides are used to feed boring and facing heads toward the part.—Ex-Cell-O Corp.

Circle 123 on postcard for more data

Welding Chamber

Plexiglass "igloo" protects titanium from the atmosphere during welding.

Protective chamber permits welding to be done in the presence



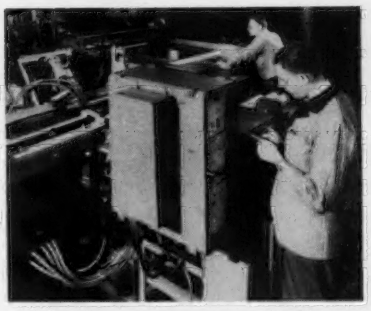
of inert gas such as argon—an element which does not affect the metal.

Hemispherical enclosure is made of transparent Plexiglas acrylic plastic, mounted on a metal base plate to which it can be sealed. The plastic dome is fitted with gloved armports.—Rohm & Haas Co.

Circle 124 on postcard for more data

Spotwelding Control

Electronic spotwelding control utilizes digital and analog computer elements, and employs the feedback principle. Called the Monautronic V-2 Control, feedback spotwelding unit cannot produce a substandard



weld without immediately "locking-out." Suitable for use on any metal that can be resistance welded.—The Budd Company

Circle 125 on postcard for more data

continued on next page

New for Production

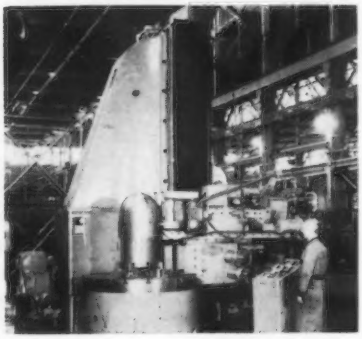
Computer "Grows"

Low-cost "growable" analog computer is designed for "desktop" use. Unit is built on a modular system; more complex components can be added to the computer as requirements dictate. By expanding the basic desktop unit to a complex floor model at a cost of about $25,000, a firm can add such components as a pre-programmed, removable patchboard system, up to 64 amplifiers, electronic multipliers and diode function generators.—Bowman Instrument Corp.

Circle 126 on postcard for more data

Contour Grinding

Linear and non-linear contours of missile nose-cones and other convex surfaces can be accurately produced by a new single-head grinder with tracer control and automatic swiveling.



The first of the new machines —with a 66-inch table and a maximum work-height of 8 ft—has been delivered to Avco Corporation's Lycoming Div.—The Bullard Co.

Circle 127 on postcard for more data

Oxygen Unit

Transportable unit produces an unlimited supply of oxygen from the atmosphere and eliminates the usual heavy steel supply cylinders.

Called AerOxy-Gen, the device delivers the gas at approximately five psi less than one minute after activation.—Aerojet General Corp.

Circle 128 on postcard for more data

Rigid Test Fixture

Environmental test fixture may be used interchangeably for vibration shock and acceleration tests to meet requirements of a rigid, resonant-free mounting.

T-type fixture of cast magnesium, can test specimens in three mutually perpendicular axes, simultaneously.—Avco Research & Advanced Dev. Div.

Circle 129 on postcard for more data

MONROVIA AVIATION *produces*

PRE-FLIGHT AIR CONDITIONING EQUIPMENT

with built-in RELIABILITY

Monrovia Aviation's Ground Support Air Conditioning Equipment is operational with the Bomarc Missile.

New Books AND Reports

HELICOPTER DYNAMICS AND AERODYNAMICS. P. R. Payne. Macmillan, 1959, 442 pp. $17.00. Written from the viewpoint of a practicing aerodynamicist and project engineer, this book assumes a basic knowledge of helicopter theory. Classical aspects of vertical flight have been correlated with practical results, keeping in mind the requirements of the industry. Chapters are devoted to the following subjects: (1) General Aerodynamics; (2) Induced Aerodynamics; (3) Fundamentals of Rotor Dynamics; (4) Dynamics of Rotors with Hinge Constraint; (5) Flapping Stability and Blade Movements in Gusts; (6) Performance; (7) Stability and Control; (8) Rotor Vibration; (9) Ground Resonance and Vibration due to Rotor Resonance; (10) Control Loads and Vibration; (11) Blade Flutter and Rotor Weaving; (12) Blade Flexing and Resonance.

AIRCRAFT WEIGHT & BALANCE CONTROL. H. G. D'Estout. Aero Publishers, 1959, 128 pp. $3.25. This is the third edition, revised and enlarged, covering general principles. It is written and illustrated in a manner easily understandable by maintenance personnel. Topics discussed include: basic measurements and computations, weight shifting, and alterations, weighing, and loading procedures, etc. Most major types of aircraft are covered.

PLASTICS SAFETY HANDBOOK. Society of the Plastics Industry, Inc., 1959. 200 pp. $5.00. This is the result of several years of voluntary work by specialists in the field of accident prevention, particularly in fire prevention, health, inspection, maintenance, materials handling, etc.

continued on next page

Built-in Reliability is a bonus design characteristic you can depend on in Monrovia Aviation's Ground Support Air Conditioning Equipment.

The portable unit illustrated fully meets all Military Specifications for air conditioning performance during pre-flight checkout of missiles and aircraft. Construction is rugged yet precise, with emphasis on airframe aluminum design for minimum weight and maximum strength. Controls are human-engineered for easy operation and maintenance. The entire unit has been carefully designed with *built-in reliability* constantly in mind!

MILITARY AND COMMERCIAL AIRCRAFT ASSEMBLIES

HONEYCOMB BONDED STRUCTURAL UNITS

ELECTRONIC GROUND SUPPORT EQUIPMENT

• *Write for Product Brochure No. AC 5.01.*

MONROVIA AVIATION *Subsidiary of*

801 Royal Oaks Drive, Monrovia, California
Phone: ELliott 8-3211

MONROVIA AVIATION

"Airframe components and Ground Support Equipment with Built-in Reliability!"

Circle 37 on Inquiry Card

OTAL

APABILITIES

WITH HONEYCOMB BONDED ASSEMBLIES . . . STRUCTURAL COMPONENTS AND GROUND SUPPORT AIR CONDITIONING SYSTEMS

MA — **MONROVIA AVIATION:** Producers of precision aircraft structural assemblies, Monrovia Aviation's products are installed on America's principal military and commercial jet aircraft. This Subsidiary also designs and manufactures customized portable air conditioning units for missile ground support purposes.

WG — **WHITTAKER GYRO:** Leading designer and manufacturer of electromechanical and non-electric gyroscopes, including rate gyros vertical gyros, and position gyros. In addition, this Division is active in the sub-systems field with stable platforms, inertial guidance equipment, and auto pilots for missiles.

WC — **WHITTAKER CONTROLS:** Designs and produces aircraft and missile fluid control systems, subsystems and components. WC Products are in every production military aircraft and commercial airliner. In many of the nation's missile programs, Whittaker is also solving extreme fluid control problems.

TS — **TELECOMPUTING SERVICES:** Skilled in the establishment and operation of data processing centers, primarily for military and civil agencies of the Government. At White Sands Missile Range, TSI processes and analyzes missile test data. At Vandenberg AFB, this Subsidiary provides data processing services for SAC's 1st Missile Division.

ES — **ELECTRONIC SYSTEMS:** Specialists in systems management, this Division also designs and manufactures a wide variety of equipment in the fields of electronics and nucleonics for highly classified Military Programs. In addition, Electronic Systems designs and produces Air Traffic Control equipment for the Federal Aviation Agency.

DI — **DATA INSTRUMENTS:** Leading designer and producer of data reduction systems for ground support and range instrumentations. Product line includes shaft rotation digital equipment, decommutators, and other highly complex and specialized instruments for missile and aircraft testing, telemetering and in-flight operation.

EC — **ELECTRONIC COMPONENTS:** Designs and produces components, including magnetic amplifiers, transformers, micro-miniature relays, delay lines and high temperature ceramic capacitors. These reliable components are being selected for installation in many of the country's principal missile and space programs.

CB — **COOK BATTERIES:** Designers and manufacturers of automatically and manually activated silver zinc batteries for specialized missile application. These auxiliary power units provide primary or secondary electrical power. This subsidiary also produces power conversion and other electronic apparatus.

TELECOMPUTING CORPORATION

Los Angeles, California

Telecomputing Corporation is a unique combination of carefully integrated organizations. It is staffed with scientific talent of rare ability, created for the purpose of managing entire Space Technology and Weapon System Projects. Telecomputing is developing *advanced concepts* in industrial and military control systems.

this jet gets built faster... with Osborn power brushing

Not long ago, one of America's top jet engine-makers flew straight into a production bottleneck. To remove sharp edges and burrs from a crucially important part, it was hand-filed and emery-rubbed—a job that took a full 80 minutes. Today, an Osborn Metal Finishing Machine does the same job in just 8 minutes . . . *10 times as fast.* And the quality is higher, the finish more uniform and precise. This is typical of the way Osborn metal finishing methods are helping America's leading industries. To find out how Osborn can help *you* speed production, cut costs and improve product quality, write *The Osborn Manufacturing Company, Dept. AM-10, Cleveland 14, Ohio.*

OSBORN®

Metal Finishing Machines... and Methods • Industrial Brushes • Foundry Production Machinery

New Books Received

continued from page 63

TECHNICAL REPORTS

The following reports may be obtained from the Office of Technical Services, U.S. Dept. of Commerce, Washington 25, D.C.

MECHANICAL PROPERTIES OF 17-7 PH AND PH 15-7 MO. STAINLESS STEEL. A. W. Brisbane, Wright Air Development Center, U. S. Air Force. Jan. 1959. 38 pages. Mechanical properties of two stainless steels, 17-7 PH (RH-950 Condition) and PH 15-7 MO. (RH-950 and TH-1050 Conditions), were investigated. $1.00. (Order PB 151703).

PROPERTIES OF POLYETHYLENE AND RELATED POLYMERS. C. Heller, S. Levinson, and C. Nudelman, TRG, Inc., for Wright Air Development Center, U. S. Air Force. The possibility of using polyethylene or other polymers in radiation shielding led to this research into the methods of production, properties, and structure. Interaction of polyethylene and radiation are also treated. $1.50. (Order PB 151584).

LUBRICATING OILS AND GREASES IN THE SOVIET UNION. N. Cheremeteff, Engineer Research and Development Laboratories, U. S. Army. May 1958. 114 pages. The report is divided into three chapters: Lubricants, Silicons, and Oil Additives; and Greases. $2.50. (Order PB 151294)

THERMOELECTRICITY ABSTRACTS. References to the literature on research, development, and application of thermoelectricity accumulated by the Library of the U. S. Naval Research Laboratory. The two volumes appear under the same title, "Thermoelectricity Abstracts." They are PB 151657, May 1959, 112 pages, $2.50; and PB 151810, Aug. 1959, 81 pages, $2.25.

Men on the Move

William C. House
Aerojet General

Dr. John V. Atanasoff
Aerojet General

WILLIAM C. HOUSE, appointed director, Systems Management, Aerojet General Corp. DR. JOHN V. ATANASOFF, appointed Vice President, Atlantic Div.

ALGIE A. HENDRIX, appointed manager of the AC Spark Plug Division operations in Milwaukee. ROBERT G. BROWN, appointed director of Advanced Concepts Research and Development.

DONALD T. ATKINSON, appointed manager of marketing for General Electric Company's Missile and Space Vehicle Department. WILLIAM J. CONNOR, JR., appointed manager of defense and business planning at the department. EDWARD A. MILLER, named manager of the Discoverer program at the department. GENE R. PETERSON, named general manager of the Ordnance Department.

Loren A. Murphy
Goodyear

Carl F. Schaefer
Norden Div.

LOREN A. MURPHY, appointed vice president, Goodyear Aircraft Corp.

CARL F. SCHAEFER, named engineering manager; ERNEST J. GREENWOOD, named operations manager; at United Aircraft Corp's Norden Div.

J. O. MOXNESS now heads Douglas Aircraft's commercial sales office in New York. J. S. FARRA, appointed to succeed Moxness as director of domestic commercial sales.

R. J. PFEIFFER, named manager of commercial aircraft marketing activities at the Los Angeles division of North American Aviation.

DR. NICHOLAS A. BEGOVICH, appointed assistant manager of Hughes Aircraft Company's Ground Systems Group. DR. ARNOLD M. SMALL, appointed manager of the product effectiveness laboratory of the Group.

JAMES A. BURNS, named director of long-range planning of the Systems Division of Bendix Aviation Corp. DR. NAZZARENO P. CEDRONI, appointed technical director of the division.

DR. HAROLD W. RITCHEY, appointed vice president in charge of rocket divisions, Thiokol Chemical Corp.

GUSTAVE A. BLEYLE, JR., named head of the new Santa Monica office of Arthur D. Little, Inc.

DR. CLARK T. RANDT, appointed director of the new office of Life Sciences of the National Aeronautics and Space Administration.

DR. ROBERT A. BASS, named chief scientist for Aeronca Manufacturing Corporation's Aerospace Div.

DWIGHT L. UMSTEAD, JR. and WILLIAM CONNAUGHTON, JR. appointed sales engineers for the Electron Tube Products department at the Red Bank Div. of Bendix.

HENRY M. CROSSEN, appointed director of manufacturing for Clearing, Div. of U. S. Industries, Inc.

ADM. SHERMAN E. BURROUGHS, JR., USN, (Ret.), named special assistant to the president at Librascope Div., General Precision, Inc.

HAROLD COOPERMAN, named manager of customer service for Rheem Semiconductor Corp.

CLYDE SKEEN joins Temco Aircraft Corp. as executive vice president and general manager. EARL H. FLATH, JR. has jointed Temco Electronics Div. as a senior scientist.

ROBERT S. CAMERA, Capt. USN (Ret) has joined Piasecki Aircraft Corp., Philadelphia, as Executive Engineer.

David S. Lewis
McDonnell

Oscar F. Carlson
Martin

DAVID S. LEWIS, named senior vice president-operations, at McDonnell Aircraft.

DR. ALBERT C. HALL, named Martin's vice president of engineering. DR. WILLIAM L. WHITSON, appointed director of advanced programs at Martin—Denver. OSCAR F. CARLSON, named assistant to the general manager at Martin — Denver. LARRY M. HAYES, named an assistant to the corporate director of Information Services, at Martin—Baltimore.

BRIAN O. SPARKS, appointed Deputy Director of the Jet Propulsion Laboratory at Cal. Tech.

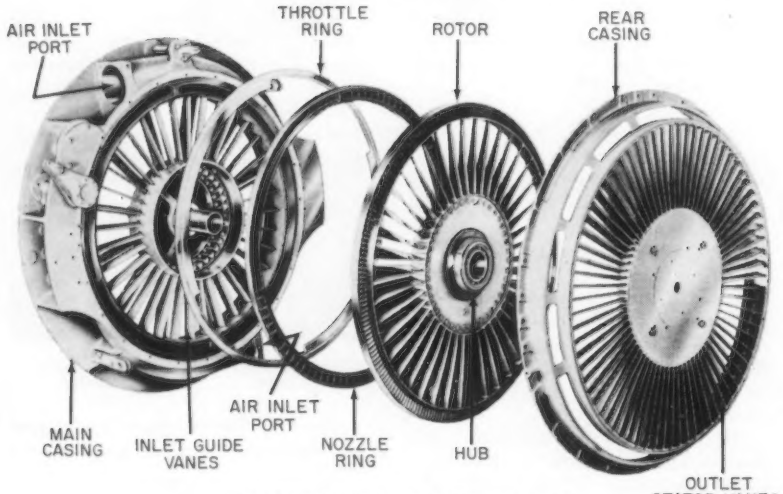
LLOYD R. EVERINGHAM, appointed director of the Ryan Aeronautical Company's Space Lab, with responsibility for operating Ryan's newly-acquired subsidiary, Aerolab Development Co.

DR. ANTHONY GANGI and DR. HAMILTON WRIGHT, appointed to the technical staff at Space Electronics Corp.

H. C. JONES, formerly chief of manufacturing control, was named manager of material; JACK HAYNES, appointed chief of manufacturing control, at Convair—Fort Worth.

Industry Notes

BRITISH VTOL FAN DESIGN



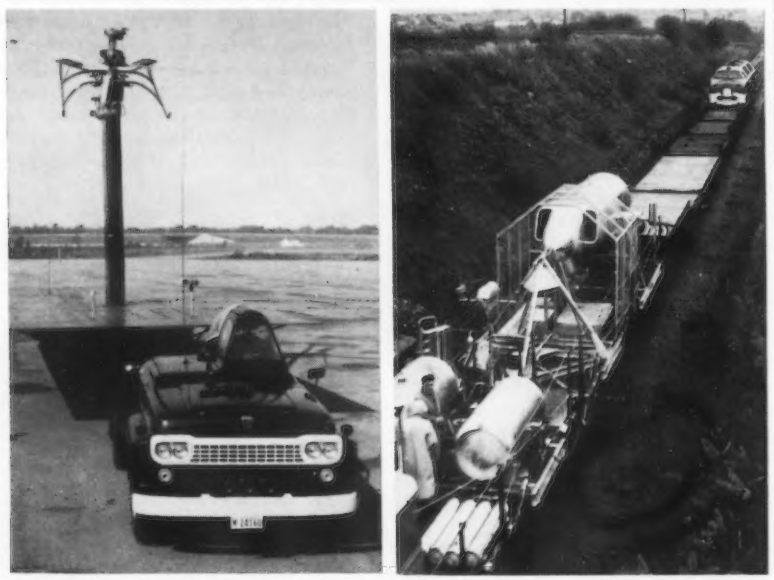
EXPLODED VIEW OF CONTROL FAN

A vertical-lift fan that can be controlled to give instant variation of thrust about a mean value has been developed by Boulton Paul Aircraft Ltd., U.K. It has been designed to operate on the relatively cold air tapped off turbine compressors. As a complete unit it is thin enough to be mounted within a wing profile with axis of rotation normal to wing surface. Total depth needed is 6 in.

Basically, it is a single-stage fan driven by a turbine collar around its periphery. Compressed air is led into the turbine via two inlets in main casing. Inlets are tangential to fan diameter, and air passes through volute ducts within the casing to two narrow ports. Each port subtends an angle of 74½ deg around the periphery and is situated diametrically opposite the other. Flow through the ports is controlled by a throttle ring actuated by a rack and pinion quadrant.

Since the turbine is of the impulse type it is necessary for the impinging air to have as much momentum as possible. To achieve this air is accelerated to supersonic velocity while passing through a nozzle ring. This ring is placed between the ports and turbine collar. Speeding up is caused by the nozzle ring restricting the flow area, and the associated pressure-drop takes place entirely within the width of the nozzle. This 52-lb. unit gives variation of ±150 lb about a mean thrust of 550 lb, at 6000 rpm.

Since there is only one continuously moving part, the fan rotor, it is lubricated by a total-loss system.



VTOL TESTS include Cornell Aeronautical Laboratory tower which telescopes so tests can be made in or out of ground effect. French facility (right) has diesel pulling while engine thrust pushes. Test aims at simulating engine landing against its own thrust.

CAN YOU GUESS

The Rupture Pressure Of A ¼" Rupture Disc Made From This Paper-Thin Piece Of Stainless Steel By BS&B?

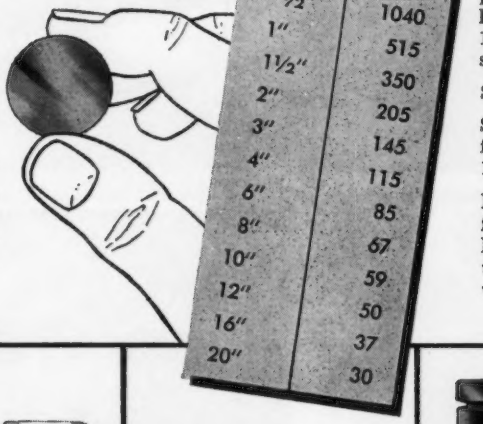
Rupture Disc Metals

Aluminum	Platinum	Nickel
Silver	Stainless	Monel
Copper	Inconel	

Rupture Discs are performing a wide variety of pressure relief and actuation functions on many of today's most advanced aircraft, missiles, rockets and submarines.

Here we show a few of these functions to illustrate the versatility of the rupture disc's basic principle in application and design. Perhaps one of them will suggest an answer to your pressure control requirements.

ANSWER:



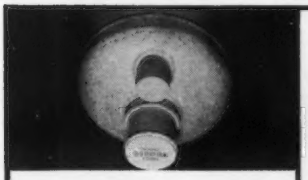
Size	Rupture Pressure PSI @72° F.
¼"	2125
½"	1040
1"	515
1½"	350
2"	205
3"	145
4"	115
6"	85
8"	67
10"	59
12"	50
16"	37
20"	30

Pressure as low as 5 psi can be attained in large diameters; up to 100,000 psi in small sizes.

Sizes from ⅛ inch up.

Service temperatures from sub-zero up to 1000° F.

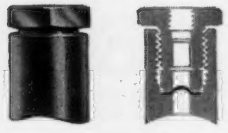
BS&B will design and fabricate any device to hold the rupture disc to your space and weight specifications.



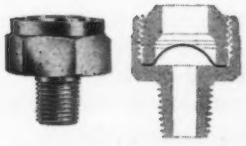
Rupture disc in larger fitting restrains the thrust of a "Jato Bottle" until the ignited propellant develops a specified pressure. When the desired thrust value pressure is reached, the disc ruptures to provide instantaneous exhaust and resultant thrust. Disc in the small fitting is a safety device for overpressure relief.

Rupture disc in this fitting is used in underwater service. At a specified pressure the disc ruptures to actuate a trigger mechanism.

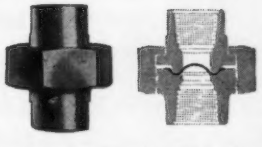
This device fits in the outer shell of a vacuum insulator vessel containing a fuel component. The rupture disc protects against dangerous pressure build-ups which might occur if the inner shell should break or leak.



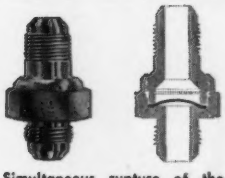
This rupture disc fitting is used on seat ejection mechanisms to lessen shock by the dissipation of excess thrust pressure.



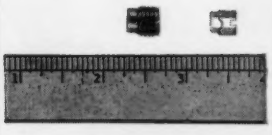
This disc assembly is used to protect against overpressure in air conditioning systems of commercial aircraft.



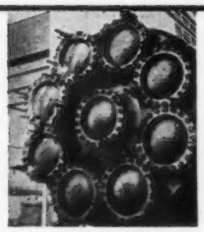
Here a rupture disc serves as a vital component in power supply of nuclear powered submarine.



Simultaneous rupture of the discs in two of these fittings triggers the mixing of a fuel and oxidizer.



Rupture disc in this tiny fitting protects against overpressure in a missile's hydraulic control system.



Large diameter (24") Safety Heads are fitted in manifold to provide overpressure protection on this engine test chamber.

BS&B — ANOTHER EXAMPLE OF PRODUCT LEADERSHIP

May we suggest further investigation of rupture disc applicability to your pressure control requirements? For engineering consultation call or write . . .

BLACK, SIVALLS & BRYSON, INC.

Safety Head Division, Dept. 2-GC4
7500 East 12th Street
Kansas City 26, Missouri

OFFICIAL UNITED STATES NAVY PHOTOGRAPH

This great seaborne health center will carry a new kind of aid abroad—*with your help*. Part of the people-to-people project Hope, it will enlist 200 specialists in sharing our health skills.

Ambassador with a blackboard, the Hope specialist will help the often woefully few local medical technicians train helpers. The result: many more hands. And that means one Hope dollar is multiplied many times over.

YOUR HELP CAN COME BACK A HUNDRED TIMES OVER

One local doctor for 100,000 people. These are the odds Hope may face. Yet Hope can mean so much. The health of this child. The health of five Indonesians. *Trained* hands and only a dollar's worth of penicillin can cure them of crippling yaws.

If enough of us help, the S.S. Hope will be outbound in 1960. First port of call: Indonesia. A bold health project called Hope will be underway.

The need is crucial. Many places, too many health hazards exist. Too many people robbed of the will to live. Too few hands to help. Often, a doctor for 100,000.

Hope's approach is *practical*. Help where a nation's doctors ask help. Help them help themselves to health. By training, upgrade skills—multiply hands. Hope's doctors, dentists, nurses, and technicians will man a center complete to 300-bed mobile unit and portable TV.

You can not only make every dollar do the work of many, you can earn a priceless dividend. With health comes self-respect. People at peace with themselves are less likely to war with others.

Hope is *yours* to give. It's a people-to-people project. For one year's worth, 3½ million Americans must give a dollar. Don't wait to be asked. Mail a dollar or more now to HOPE, Box 9808, Washington 15, D.C.

ADVERTISING COUNCIL · PUBLIC SERVICE

HELP LAUNCH HOPE

Industry Notes

YHC-1B CHINOOK is turbine-powered, tandem-rotor. It can carry two-ton internal payload of Pershing components.

NASA VTOL Report

NASA recently issued results of its studies on longitudinal aerodynamic characteristics of three prop-driven VTOL configurations in the transition speed range. Wind tunnel studies on tilt-wing, deflected slipstream, and combination tilt-wing-deflected slipstream showed:

- Tilt-wing requires least power in hovering.
- Combination tilt-wing-deflected slipstream has "relatively low" power requirements throughout the transition speed range.
- Power requirements of deflected-slipstream configuration are "greatly increased in the region on ground effect."

Aerospace Log

Feb. 11—Second X-15 reaches 80,000 ft., Mach 2.

Feb. 24 — Titan carries data capsule 5000 miles into South Atlantic.

Feb. 25—Two-stage Pershing makes first flight from Canaveral. As was planned, only first stage fires for 20-mile test.

Feb. 27 — First attempt to launch Midas satellite fails.

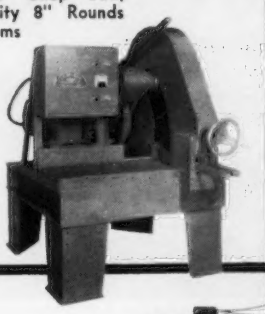
March 5 — Operational Atlas blows up on launch pad during fuel transfer training exercise.

March 7 — Atlas fired 6300 miles first time with all-inertial guidance system. Titan fired with radio-inertial guidance, falls short because of second stage failure.

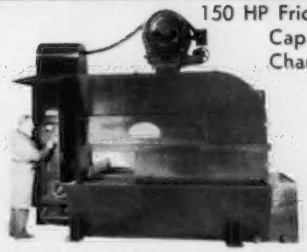
March 11—Pioneer V fired into solar orbit between orbits of earth and Venus. Three stage Thor-Able launches vehicle.

Ty-Sa-Man America's Most Complete Line of Industrial Sawing Machinery

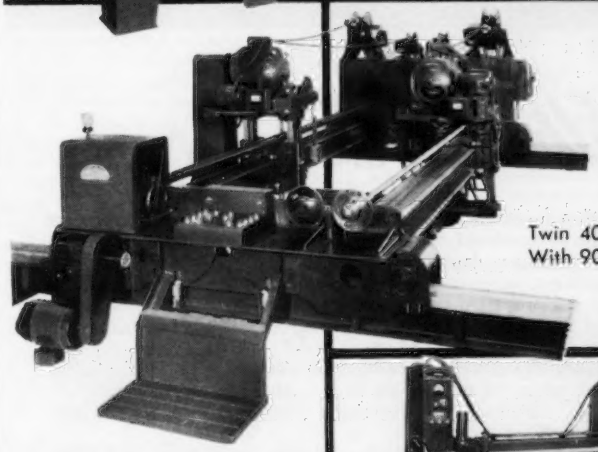
30 HP Chop Saw, Capacity 8" Rounds or Beams



150 HP Friction Saw Capacity 24" Channel

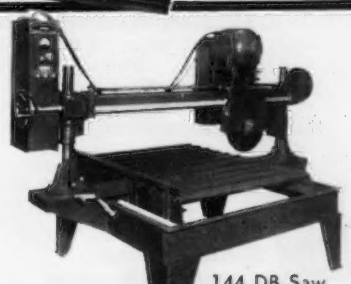


75 & 30 HP Model Available



Twin 40 HP Gantry With 90° Swivel Heads

If you can't cut it with a standard saw . . . call us! Ty-Sa-Man has built thousands of special and standard saws, one of which may solve your problem. If not, our engineering staff is at your disposal.

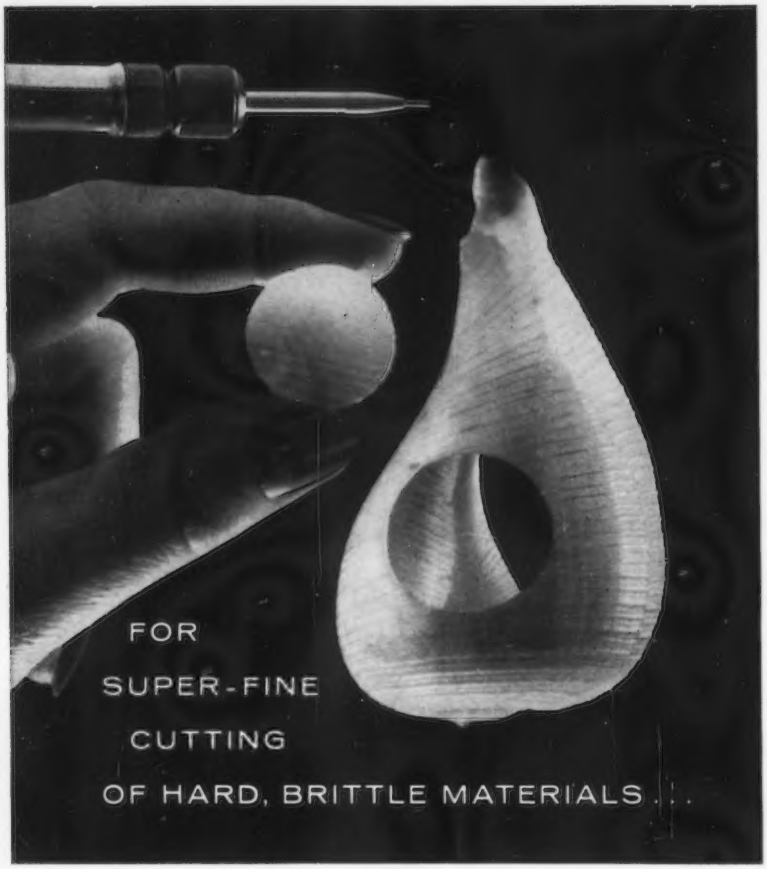


144 DB Saw for Plate

TY-SA-MAN
MACHINE COMPANY, Inc.
1135 White Avenue
Knoxville 1, Tennessee

Write Today for Free Brochure
A brochure pictures and describes the functions of many metal saws. If you have a cutting problem, write or call today.

Circle 34 on Inquiry Card



THE S.S.White Industrial Airbrasive® Unit

We cut a section from this fragile sea shell just to show that *in a matter of seconds* almost any hard, brittle material can be cut or abraded with the S.S. White Industrial Airbrasive Unit.

Cool, shockless, super-precise, the unit uses a controlled stream of fine abrasive, gas-propelled through a small nozzle. It is so flexible in operation that the same simple tool can frost a large area or can make a cut as fine as .008" . . . on a production basis!

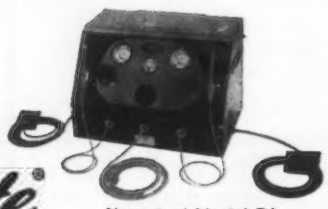
Almost every day new uses are being discovered for the Airbrasive Unit, in the lab or on the production line . . . shaping . . . deburring . . . wire-stripping . . . drilling . . . engraving . . . frosting . . . materials testing . . . cleaning off surface coatings.

All types of hard brittle materials . . . glass, germanium and other fragile crystals, ceramics, minerals, oxides, metal, certain plastics.

Send us your most difficult samples and we will test them for you.

1089

SEND FOR
BULLETIN 5705A
...complete information



S.S.White®

New dual Model DI

S. S. WHITE INDUSTRIAL DIVISION • Dept. 18-A • 10 East 40th Street, New York 16, N. Y.

Industry Notes

Mercury Path Indicator

An Earth Path Indicator developed by Minneapolis Honeywell will permit the first Mercury astronaut to "see" where he is over the earth at all times during orbit. It will be the prime source of position information for landing if the astronaut loses contact with ground tracking stations.

A globe inside the shoe-box sized indicator revolves slowly to duplicate the position of the earth.

The astronaut will view the globe through a window on his instrument panel as if he were actually seeing the earth below him through a window in his capsule.

Markings on the globe show longitude, latitude, continents, topography and major cities. A bull's-eye sight of the window pinpoints the capsule's location over the earth. Other markings pinpoint the place where the capsule would land when ejected from orbit.

Mercury Nerve Center

Stromberg-Carlson, San Diego, will design, build and install the vital monitor and control display system for Project Mercury. The display system, described as the "nerve center" for the project, will be installed in the NASA control center at Cape Canaveral, Fla.

The center will display information about the flight gathered from a world-wide network of tracking and telemetry stations and several large computers.

Data imputs such as the astronaut's heart rate, blood pressure, and body temperature; and the capsule's oxygen pressure, acceleration rate, attitude and route determination will be fed into the center and visually displayed.

The monitor and control display system, as designed by Stromberg-Carlson, will be housed in a room 40 ft. wide by 60 ft. long.

LARGE AND SMALL of ground effect machines is illustrated by Saunders-Roe experimental Hovercraft and Bell Helicopter's "air scooter." Former weighs 8500 lb. and can carry 20 marines. Latter weighs 160 lb. holds one man who shifts his weight for turns.

R & D Briefs

Experimental laminates to be studied for missile applications at Taylor Fibre Co. include web-resin combinations with high temperature resistance.

Missile-impact underwater Detection System, developed by Bell Telephone, will aid nose cone retrieval on Pacific as well as Atlantic Missile Range. Missile Range "Hydrophone" Stations are being set up on islands in the Pacific.

Project Mercury high altitude simulator—being built for the astronauts by Tenney Engineering —will hold actual Mercury capsule. It will simulate altitude of 225,000 ft and possible dive rates.

Production Techniques

Dynamic analyzer to simulate conditions of space will be installed at Wright-Patterson Air Force Base. To be completed in two years, it will test systems and subsystems of satellites and advanced aircraft. Machine moves violently in spider-like fashion for roll, pitch and yaw. Builder: Minneapolis-Honeywell.

Fibre-glass-wrap technique has cut weight of Atlas thrust chambers.

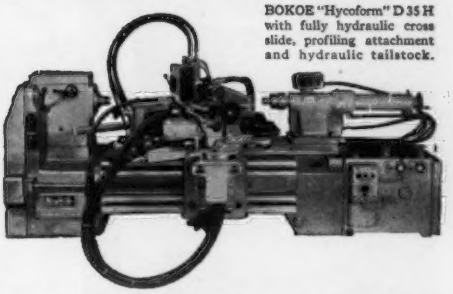
"Machining" speeds of 250,000 ft. per min have been obtained by researchers at Lockheed's California Div. Tests were made on high-strength steel and titanium alloys. Investigation of ultra - high - speed machining uses a 20-mm cannon, which fires workpiece past the cutting tool.

You can Adapt **BOKOE**

Flow Forming & Spinning Lathes To Your Exact Production Needs

From simple spinning lathes to fully hydraulic "Hycoform" machines with built-in copying attachment and automatic cycle control.

BOKOE adaptability can save you money—and simplify your spinning or flow forming production problems. BOKOE's "building block" design lets you choose a machine suited exactly to your production requirements. You don't have to "get by" with sub-capacity machines, or over-invest in more machine than you need. And you can extend the production performance of your BOKOE machine whenever necessary.



BOKOE "Hycoform" D 35 H with fully hydraulic cross slide, profiling attachment and hydraulic tailstock.

From basic design with hand rest and mechanical tailstock, BOKOE machines can be extended to include:

- Mechanical, hydro-mechanical or fully hydraulic cross-slide
- Front only or combined front & rear cross-slides
- Mechanical or fully hydraulic tailstock
- Built-in, hydraulic copying attachment
- Automatic cycle control

BOKOE Light Spinning Lathe D 35 L with hand rest and mechanical tailstock.

There's a BOKOE machine for every type of spinning and flow forming operation—for light and heavy work on ferrous and non-ferrous materials—for cylindrical and conical shapes and nose cones used in aircraft and missile applications.

- Flow forming of Aluminum up to ⅜" thickness
- Flow forming of soft steel up to ¼" thickness
- Swing up to 86" maximum
- Longitudinal slide movement of 40"

Write For Information

COSA *Importers of Leading Precision Machine Tools Nationwide Sales and Service*
COSA CORPORATION, 405 LEXINGTON AVENUE, NEW YORK 17, N.Y.

IN CANADA contact COSA CORP. OF CANADA, LTD., 1160 Lakeshore Rd., Long Branch, Toronto 14, Ont.

Proved! New, Better Way to Seal Drilled Holes with . . .

Less weight!

Less cost!

NEW PIN-PLUGS°

Seal simply, positively Prevent costly leaks!

Now — forget conventional, costly methods of sealing holes that serve as flow or pressure passages. The Lee "Pin Plug" is a cylindrical plug with a tapered reamed hole partway through its center and numerous small grooves on its outside surface. Simply place it into reamed hole and drive in the tapered pin until ends are flush. Controlled expansion causes grooves in plug to "bite" into casting and form independent seals and retaining rings. Extensive laboratory tests report no leaks under normal pressures, often show bone dry seals up to pressures of 40,000 psi.

Now successfully and widely used on aircraft and missiles — for pumps, servo valves, regulators, etc. Available steel and aluminum and in both long and short series.

° Pat #2,821,323

LEE CO.

SOME TERRITORIES STILL OPEN FOR QUALIFIED TECHNICAL SALES REPRESENTATIVES.

Write today for Standard Sizes and Engineering Data

THE LEE COMPANY OLD SAYBROOK, CONN.

Industry Notes

Contracts

Radio Corp. of America—$474,831,000 for work on the Air Force's Ballistic Missile Early Warning System.

McDonnell Aircraft—$33,500,000 from NASA for increasing number of Mercury capsules to 20.

Convair-Pomona—$25,200,000 for additional production of the Navy's advanced Terrier missile; $19,000,000 from ARDC in initial funding of a $43-million contract for Centaur airframe and storage tanks.

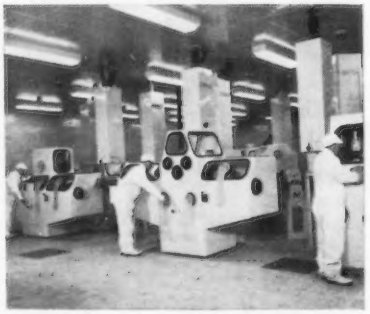
Temco Aircraft — $25,000,000 for continued development and flight-testing of Corvus for the Navy.

The Martin Co. — $12,687,000 for continued production of Army's Lacrosse.

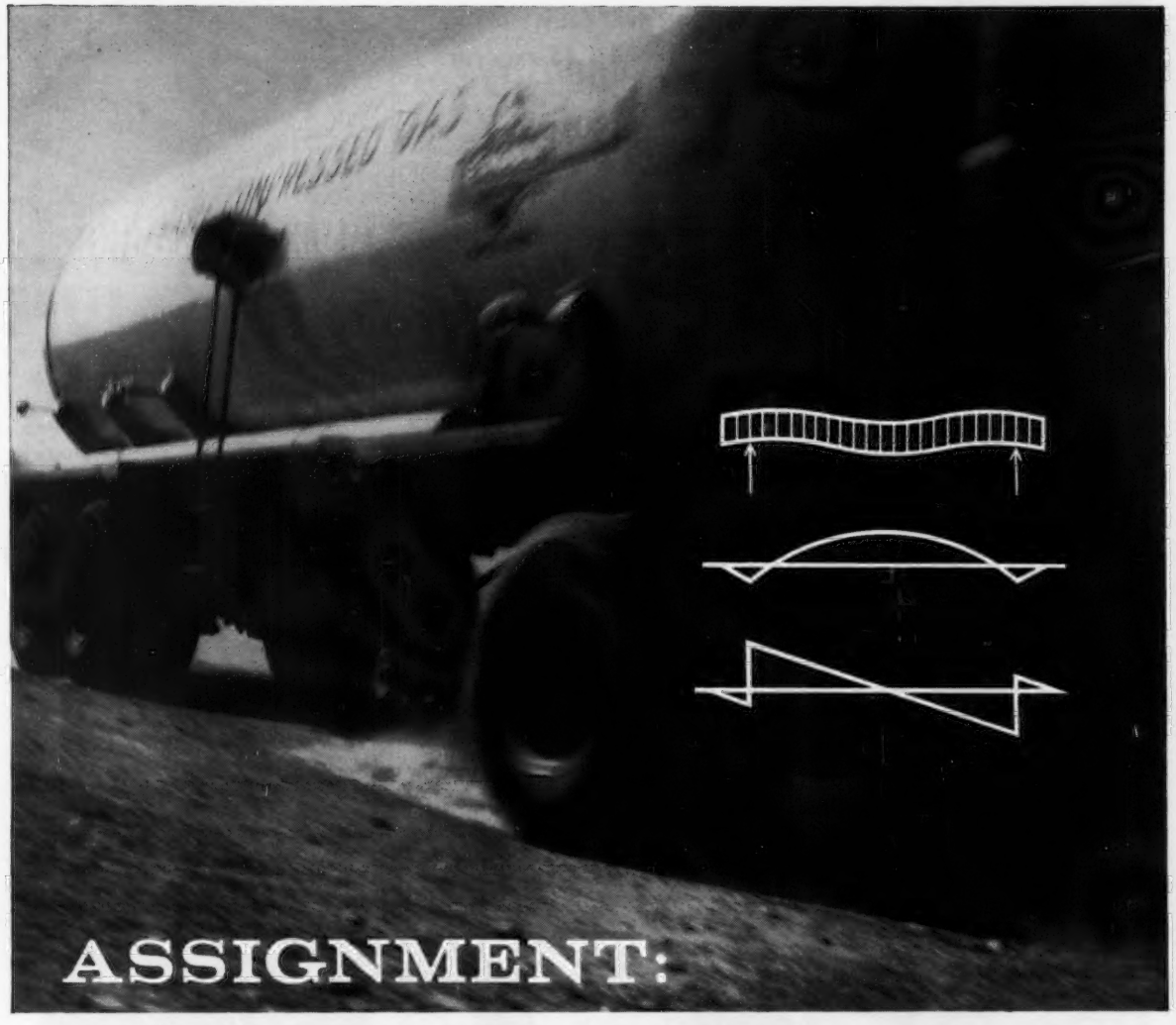
Sikorsky Aircraft—$45,000,000 for HSS-2 helicopters and parts.

Bell Helicopter — $5,000,000 from the Air Material Command for HU-IB helicopters and equipment.

Ryan Aeronautical—$5,914,000 to Ryan Electronics Div. for initial procurement of an/APN-130 doppler radar navigation sets to aid hovering of the Navy's new anti-submarine helicopters.



BERYLLIUM-MACHINING plant at Armstrong Whitworth Aircraft was recently opened. Machining takes place inside enclosed machines.



STRENGTH / WEIGHT

How Lukens *Application Research* can help you find the right steel plate for the job

Designing for maximum payload means taking maximum advantage of today's high strength steels. Experts who know these steels—from a practical as well as technical standpoint—can give invaluable assistance in the early planning stages. This is the job of our Application Engineering staff.

LPG transport tanks and power shovels are widely divergent areas in which Lukens engineers have helped increase payloads.

The use of Lukens "T-1" steel plate and heads in tanks for hauling LP-Gas has fostered an entirely new design concept in the tank truck field. This high tensile, high yield strength steel (100,000 psi) makes it possible to mount wheels *directly on the tank.* The dead weight of heavy underframes goes into payload.

Working with a major producer of power shovels, our staff suggested tough Lukens "T-1" for buckets, dipper sticks, bucket teeth and other key parts. Lightweight, welded steel plate—rather than heavy castings—added as much as 40% to load capacity.

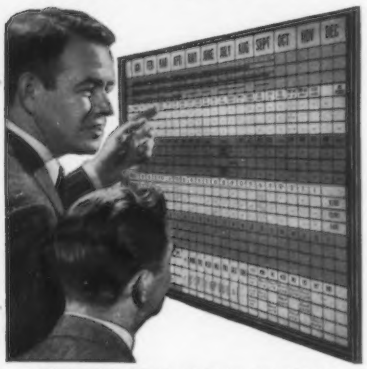
From these successful projects—and many more—our Application Engineers have gained knowledge and experience of value to design engineers. That's why we say... *if your assignment is strength/weight, let it be our assignment, too.* Contact Manager, Application Engineering, L-40 Services Building, Lukens Steel Company, Coatesville, Pa.

Helping Industry Choose Steels That Fit The Job

LUKENS ®

ASK FOR THE LUKENS "T-1" STEEL BULLETIN

How To Get Things Done Better And Faster



BOARDMASTER VISUAL CONTROL

- ☆ Gives Graphic Picture — Saves Time, Saves Money, Prevents Errors
- ☆ Simple to operate — Type or Write on Cards, Snap-in Grooves
- ☆ Ideal for Production, Traffic, Inventory, Scheduling, Sales, Etc.
- ☆ Made of Metal Compact and Attractive. Over 500,000 in Use

Full price **$49.50** with cards

FREE 24-PAGE BOOKLET NO. VM-10 Without Obligation

Write for Your Copy Today

GRAPHIC SYSTEMS
Yanceyville, North Carolina

Circle 46 on Inquiry Card

Industry Notes

New Facilities

CTL Div. of Studebaker-Packard Corp. will build a new plant at Santa Ana, Calif. for actual production of high-temperature reinforced plastic components for missiles and space vehicles.

First missile depot for storing and maintaining Air Force missiles is operating at San Bernardino Air Materiel Area, Norton AFB, Calif. It will repair and store Thors, and will eventually maintain parts for Atlas and Titan.

Fairchild Engine and Airplane's plastics branch has doubled facilities at Copiague, L. I., N. Y.

National Beryllia Corp. has tripled facilities at North Bergen, N. J. for research and production of beryllium oxide ceramics.

Send for this helpful booklet covering properties and uses of Whitelight Magnesium . . .

Whitelight MAGNESIUM

Your comprehensive independent mill source of magnesium alloy . . .

RODS—⅛" dia. to 6½" dia.
BARS, STRIPS—.022" min. to 7¾" max.
SOLID SHAPES—.022" min. to 6½" circle
TUBING—¼" O.D. to 6" O.D.
HOLLOW SHAPES—¼" to 6½" circle
PLATE and SHEET—.092" to 3" thick (36" and less)

ALLOYS
AZ10
AZ31
AZ51
AZ61
AZ81
ZK60
ZK30
M-1
ZK-20
Anodes

WHITELIGHT MAGNESIUM

Your inquiry will receive our prompt attention.

WHITE METAL ROLLING & STAMPING CORP.
112 Moultrie St., Brooklyn 22, N. Y.
Factories: Brooklyn, N.Y., Warsaw, Ind.
Los Angeles Warehouse:
6601 Telegraph Rd.

Circle 45 on Inquiry Card

NEW!

SPRING & FUSE CLIPS, LOCK WASHER TERMINALS

Order from Zierick stocks for quick delivery. New terminals with #4, 6, 8 holes, spring and fuse clips made from .018 brass or phosphor bronze, hot tinned. Special parts quoted from sketches or blueprints. Production on our upright presses or multi-slide machines. Over 500 stampings and wire forms to choose from.

STANDARD ELECTRICAL PARTS delivered FAST!

Lugs • Clips • Terminals Wire Forms from Stock

Send your copy of the new Zierick catalog No. 22 TODAY!

ZIERICK MANUFACTURING CORP.

79 Rockdale Ave., New Rochelle, N. Y. • NEw Rochelle 6-8520

Circle 40 on Inquiry Card

Despite terrific temperature changes, abrasions and repeated immersions in acids, oils and water—these stainproof electrical tapes have demonstrated their ability to seal . . . hold . . . and insulate without weakening. Available in three versions to meet your Class H insulation requirements.

7000-G: Silicone adhesive on one side.

7100-G: Silicone adhesive on both sides.

7300-Extra Thin: Flexible Mylar® polyester film backing. Temperature range: 80° to +325°F.

MYSTIK TAPE

Write for samples and further information
Mystik Adhesive Products, Inc.
2635 N. Kildare Ave., Chicago 39

Circle 41 on Inquiry Card

"Information Center" for **Roebling Aircord**

Here is where the immediate response of Roebling Aircord is felt. Roebling Aircord – tinned, galvanized carbon and stainless – is made to exceed *military* specifications.

Roebling Aircord is made in a full range of sizes and constructions. Cord can be furnished in stock lengths or in complete assemblies... fittings are available for every requirement. Lock-Clad, preformed cable with aluminum tubing swaged around it, is also produced by Roebling... the original producer, and for many years the only producer.

For further information on Roebling Aircord, write to Wire Rope, John A. Roebling's Sons Division, Trenton 2, New Jersey.

ROEBLING

Branch Offices in Principal Cities
John A. Roebling's Sons Division
The Colorado Fuel and Iron Corporation

Circle 43 on Inquiry Card

Business Moves

Bendix Aviation Corp. will adopt a new name—"The Bendix Corp."—About June 1 Bendix acquired an 80 acre site in the San Fernando Valley for a planned 650,000 sq. ft. electronics center.

Leach Corp., Compton, Calif., acquired Electrospace Laboratories Inc., Pasadena, Calif., manufacturer of subminiature command receivers for missiles and space vehicles.

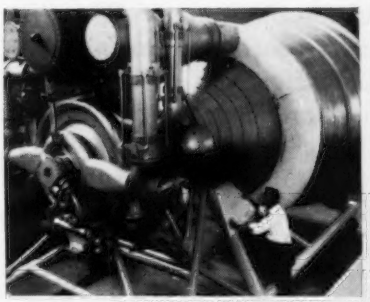
Robinson Technical Products Inc., manufacturer of shock-resistant mountings, has approved consolidation into Robinson of Kensico Tube Co.

Fairey Aviation merged its airframe and helicopter activities with the Westland Co. This reportedly clears the way for support of the Fairey Rotodyne by the British Ministry of Supplies and the government-owned British European Airways.

Patent Intelligence File Co., New Haven, Conn. introduces daily patent search and abstract service this month.

Irradiated Insulations, Inc. has been formed to produce insulated wire for the electronics, aviation and missile fields. Firm was set up by Carlisle Corp., Carlisle, Pa., and Radiation Applications, Inc., Long Island City.

Marbon Chemical Div., Borg-Warner Corp., reduced prices from seven to nine cents per lb. on truckload quantities of CYCOLAC ABS plastic.



F-1 MOCKUP is shown at Rocketdyne, which expects to have the 1,500,000-lb.-thrust engine ready for flight in four years.

Lepel

HIGH FREQUENCY INDUCTION HEATING UNITS

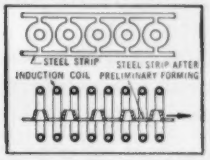
Lepel induction heating equipment represents the most advanced thought in the field of electronics... the most practical and efficient source of heat developed for numerous industrial applications. You are invited to send samples of work with specifications. Our engineers will process and return the completed job with full data and recommendations without cost or obligations.

TYPICAL INDUCTION HEATING APPLICATIONS

PLASTIC COATING OF TOOL HANDLES

A production line operation for coating handles of tools at Whitney Metal Tool Co., Rockford, Ill. uses induction heating with excellent results. The handles only are heated by induction to the desired temperature then dipped into a vinyl chloride base coating material for a short period depending upon the thickness of coating desired. The plastic coating formed on the handles is then cured by immersion in a carbo-wax bath.

FORMING OF METAL STRIP FACILITATED BY PROGRESSIVE ANNEALING



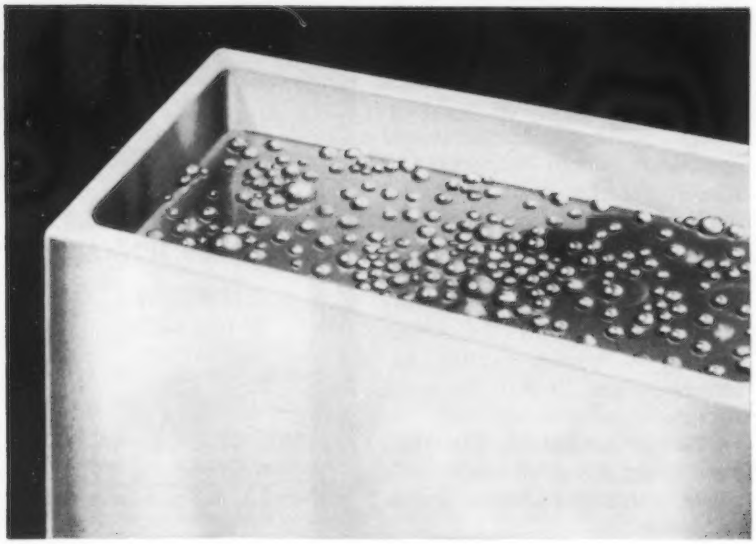
Metal forming operations which require intermediate anneals to restore ductility can be facilitated by induction annealing the strip progressively. Diagram illustrates this procedure for partially formed thin austenitic stainless steel strip. The induction annealing operation is scheduled in the production line between two press operations. Metal strip and wire of other materials are also induction annealed in this manner.

WRITE FOR NEW LEPEL CATALOG
Electronic Tube Generators from 1 Kw to 100 Kw
Spark Gap Converters from 2 Kw to 30 Kw

Lepel HIGH FREQUENCY LABORATORIES, INC.
55th ST. & 37th AVE., WOODSIDE 77, N. Y.

Circle 42 on Inquiry Card

ACOUSTICA ULTRASONIC CLEANING REPLACES OLDER METHODS!



Texas Instruments, Martin Company, Bell Telephone Laboratories and many other firms are turning to Acoustica for better cleaning ultrasonically!

Now you can clean better and faster. In seconds—all dirt, dust, and soils are "cavitated" away ultrasonically. No scrubbing, no disassembling, maintenance costs are sharply reduced. Acoustica ultrasonic systems are application tested and *certified* for your particular needs. Send for details of complete Acoustica line of the most advanced ultrasonic equipment and cleaning chemicals. Acoustica Associates, Inc., Fairchild Court, Plainview, N. Y., 1042 Aviation Blvd., Los Angeles, Calif.

CERTIFIED APPLICATIONS

acoustica

ULTRASONIC CLEANING SYSTEMS

index to advertisers

This Advertisers' Index is published as a convenience, and not as part of the advertising contract. Every care will be taken to index correctly. No allowance will be made for errors or failure to insert.

AMP Inc. 1
Acoustica Associates, Inc. 76
Aircraft & Missiles 68
Airdox-Cardox Products Co. . . 41
American Electrical Heater Co. 60
Bendix Aviation Corp.
Prod. Div. 10
Red Bank Div. 7
Black, Sivalls & Bryson, Inc. . . 67
Brady Co., W. H. 48
Cardox Div., Chemetron Corp. . 41
Chandler Evans Corp. 50
Clearing Div. . . . . B. C.
Convair (Dynapak Div.) . 3rd Cover
Colonial Rubber Co. 15
Cosa Corp. 71
Dade County Development 48
General Dynamics Corp. . 3rd Cover
Graphic Systems 74
Great Lakes Carbon Corp. 60
Handy & Harman . . . . . 2nd Cover
Hansen Mfg. Co. 58
Holex Inc. 56
Hufford Corp. 5
Lee Co. 72
Leonard Inc., Wallace O. 16
Lepel Laboratories, Inc. 75
Lukens Steel Co. 73
M. C. Mfg. Co. 8
Matthews & Co., Jas. H. 3
Mystik Adhesive Products Inc. . 74
National Machine Tool Builders Asso. 14
Osborn Mfg. Co. 64
Roebling's Sons Div., John A. The Colorado Fuel and Iron Corp. 75
Sealol Corp. 31
Simmons Fastener Corp. 13
Sinclair Collins Valve Co. 6
Staplex Co. 48
Superior Tube Co. 9
TA Mfg. Corp. 48
Taylor Fibre Co. 20-21
Telecomputing Corp. 62-63
Thermo Electric Co. Inc. 55
Ty-Sa-Man Machine Co. 69
Vascoloy-Ramet Corp. 25
White Industrial Division, S. S. 70
White Metal Rolling & Stamping Corp. 74
Zierick Mfg. Co. 74

Free Information for Readers

USE THESE TIME-SAVING POSTAGE PAID REPLY CARDS FOR MORE INFORMATION ON

USE FREE READER SERVICE CARDS

FIRST CLASS
Permit No. 36
New York, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary if Mailed in the United States

POSTAGE WILL BE PAID BY

Aircraft & Missiles
P. O. Box 74,
Village Station
Readers Service Dept. **New York 14, N. Y.**

Postcard valid 8 weeks only. After that use own letterhead fully describing item wanted. **APRIL, 1960**

Please send further information on items circled below.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180

For the following numbers pertaining to recruitment please use home address.

181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220

YOUR NAME ..... TITLE .....
COMPANY .....
PLANT ADDRESS .....
CITY ..... ZONE ..... STATE .....
PRINCIPAL PRODUCT AT THIS PLANT .....

Advertiser's Products and Services

Copies of Technical Literature

New Materials and Components

New Production Equipment

New Electronic Equipment

and

Employment Opportunities*

Circle the numbers shown in this issue and mail this card for more data on products advertised & described.

FIRST CLASS
Permit No. 36
New York, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary if Mailed in the United States

POSTAGE WILL BE PAID BY

Aircraft & Missiles
P. O. Box 74,
Village Station
Readers Service Dept. **New York 14, N. Y.**

*Please use your home address when inquiring about Employment Opportunities.

Free Information for Readers

USE THESE TIME-SAVING POSTAGE PAID REPLY CARDS FOR MORE INFORMATION ON

Advertiser's Products and Services

Copies of Technical Literature

New Materials and Components

New Production Equipment

New Electronic Equipment

and

Employment Opportunities*

Circle the numbers shown in this issue and mail this card for more data on products advertised & described.

*Please use your home address when inquiring about Employment Opportunities.

USE FREE READER SERVICE CARDS

Postcard valid 8 weeks only. After that use own letterhead fully describing item wanted.

Please send further information on items circled below. **APRIL, 1960**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180

For the following numbers pertaining to recruitment please use home address.

181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220

YOUR NAME .....TITLE.....

COMPANY .....

PLANT ADDRESS .....

CITY .....ZONE.....STATE.....

PRINCIPAL PRODUCT AT THIS PLANT .....

FIRST CLASS
Permit No. 36
New York, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary if Mailed in the United States

POSTAGE WILL BE PAID BY

Aircraft & Missiles
P. O. Box 74,
Village Station
Readers Service Dept. **New York 14, N. Y.**

Postcard valid 8 weeks only. After that use own letterhead fully describing item wanted.

Please send further information on items circled below. **APRIL, 1960**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180

For the following numbers pertaining to recruitment please use home address.

181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220

YOUR NAME .....TITLE.....

COMPANY .....

PLANT ADDRESS .....

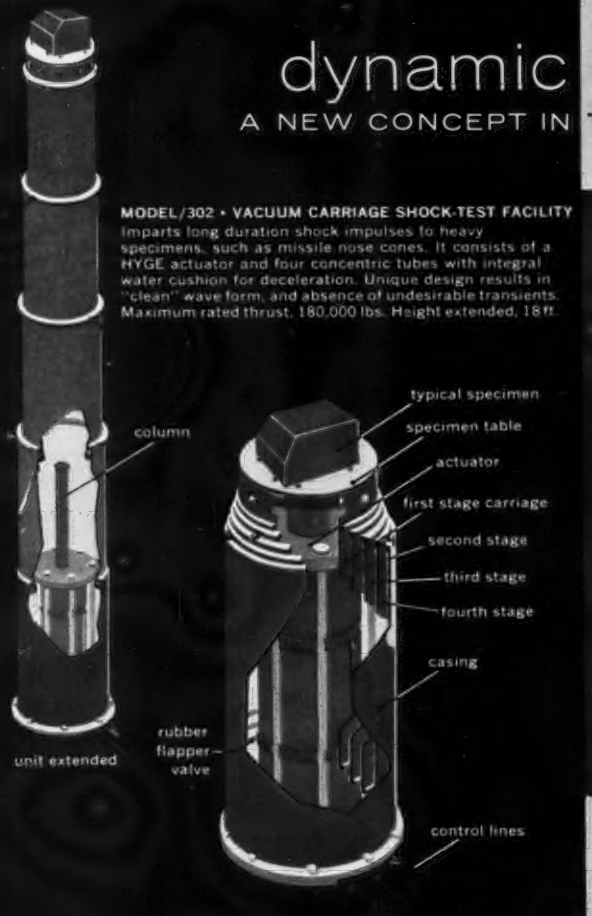
CITY .....ZONE.....STATE.....

PRINCIPAL PRODUCT AT THIS PLANT .....

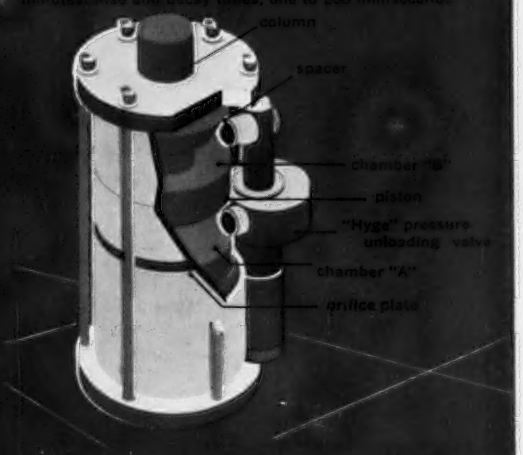
dynamic loading

A NEW CONCEPT IN TEST EQUIPMENT

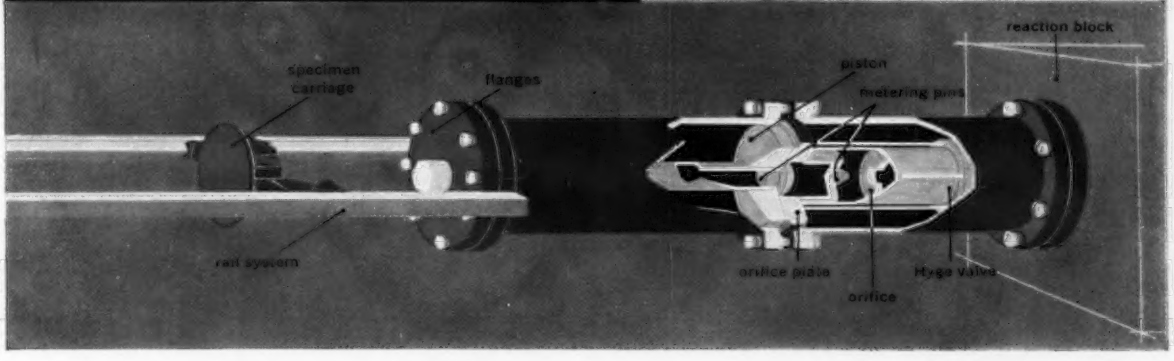
MODEL/302 • VACUUM CARRIAGE SHOCK-TEST FACILITY
Imparts long duration shock impulses to heavy specimens, such as missile nose cones. It consists of a HYGE actuator and four concentric tubes with integral water cushion for deceleration. Unique design results in "clean" wave form, and absence of undesirable transients. Maximum rated thrust, 180,000 lbs. Height extended, 18 ft.



MODEL/334 • FORCE-TIME TEST FACILITY
This machine imparts a predetermined force-time impulse to a test article with external control of force level, rise time, dwell, and decay. Typical applications: to simulate the effects of a nuclear explosion upon building foundations; to simulate stresses in a rocket engine test stand. Dwell time may vary from fractions of a millisecond to several minutes. Rise and decay times, one to 200 milliseconds.



MODEL/347 • SHOCK-TEST FACILITY
This machine provides great versatility and control of g level, duration, wave form, and specimen mass. It can produce, for example, a 3000 g short time peak, followed by a ¼ cosine impulse. Typical application, simulation of 2-phase water re-entry shock. Rated maximum thrust, 450,000 lbs. External deceleration by a 60 ft. rail system. Specimen mounted on carriage with friction brakes.



The advanced Mechanical Systems Group of Convair's Dynapak Division has pioneered in the development of dynamic loading and shock test equipment and mechanical simulators. Key element in many of these devices is the HYGE (Hi-G) pneumatically energized actuator. This power source can produce maximum thrusts of 50,000 lbs. to 500,000 lbs., depending upon the model number of the machine selected, and upon the diameter of the actuator. HYGE test equipments are characterized by exact repeatability, great versatility, ease and precision of control, and rapid operation that will permit "on-line" test of production items. HYGE equipment may be adapted to your needs by modification of standard models, or it may be completely custom designed to your requirements. Write, wire, or phone:

ADVANCED MECHANICAL SYSTEMS GROUP
DYNAPAK / CONVAIR, A DIVISION OF GENERAL DYNAMICS CORPORATION

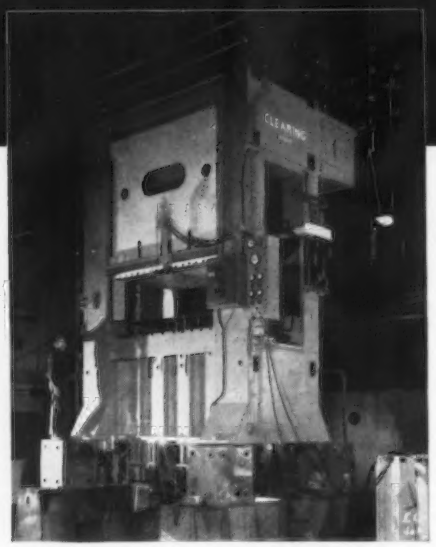
1243 Transit Avenue, Pomona, California • Phone: NAtional 3-1561

Engineers: Make your career in this dynamic and growing organization. Send your resume to William K. Stewart.

Circle 2 on Inquiry Card

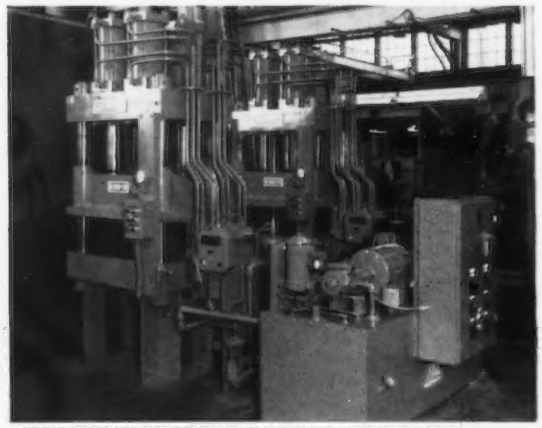
You name it—CLEARING will help you make it BETTER

with HYDRAULIC PRESSES like these...



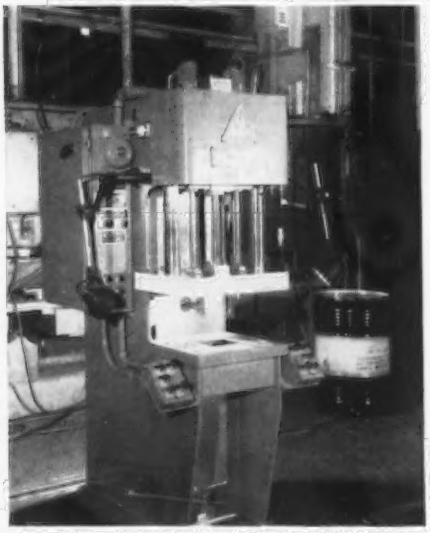
HEATING & AIR CONDITIONING PARTS—***FORMED***

Sheet metal parts are drawn on this 750 ton press designed to handle off-center loads with blank and draw dies using individually controlled cushions.



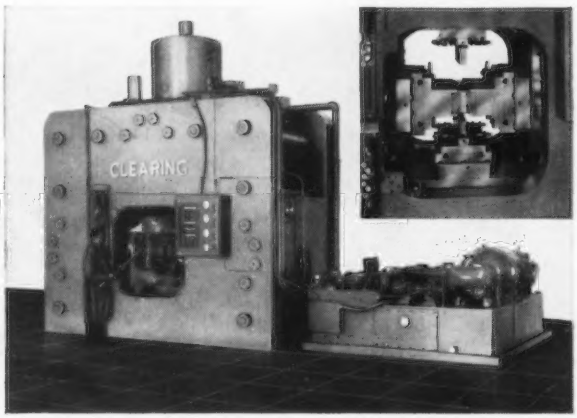
BOWLING BALLS—***MOLDING***

These two steam heated, 200 ton column-type hydraulic presses are designed for multiple cavity molding and operated from a single power source.



DIE CASTING—***TRIMMING***

High speed trimming is done on this 10 ton hydraulic gap press.



TITANIUM—***BRIQUETTING***

Four slides exerting 3,000 tons produce titanium briquettes. Inset shows 4 slide arrangement.

SEND YOUR PROBLEM TO

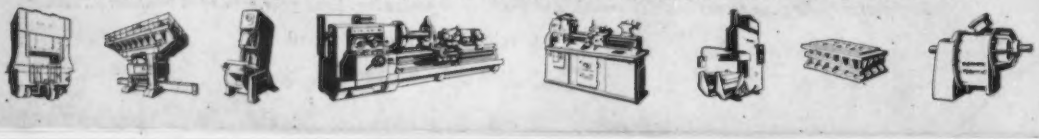
USI Clearing

DIVISION OF U.S. INDUSTRIES, INC.

6499 W. 65th Street • Chicago 38, Illinois

Plants in: Chicago, Ill. • Hamilton, Ohio • Los Angeles, Calif

Circle 3 on Inquiry Card

CLEARING MANUFACTURES AND SELLS THESE PRODUCTS

Mechanical Presses • Hydraulic Presses • Torc-Pac O. B. I. Presses • Axelson Lathes • Harrison Lathes • Special Equipment for Aircraft & Missiles Mfg. • Dies • Torc-Pac Drives